ENGINEERING DESIGN HANDBOOK

EXPLOSIVES SERIES PROPERTIES OF EXPLOSIVES OF MILITARY INTEREST

HEADQUARTERS, U.S. ARMY MATERIEL COMMAND

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ENGINEERING DESIGN HANDBOOK

PROPERTIES OF EXPLOSIVES OF MILITARY INTEREST

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*This pamphlet supersedes AMCP 706-177, 22 March 1967, including Change 1, 20 December 1967.

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PREFACE

The Engineering Design Handbook Series of the Army Materiel Command is a coordinated series of handbooks containing basic information and fundamental data useful in the design and development of Army materiel and systems. The handbooks are authoritative reference books of practical information and quantitative facts helpful in the design and development of Army materiel so that it will meet the tactical and technical needs of the Armed Forces.

AMCP 706-177, Properties of Explosives of Military Interest, is one of a series on Explosives. One hundred and ten explosive compounds or mixtures are listed herein, alphabetically, with their properties, including composition variations. These explosives were selected because of their current or probable application to military use.

The tabulated data reflect the results of tests, and were first compiled for publication at Picatinny Arsenal, Dover, New Jersey, by W. R. Tomlinson, Jr. These data were later revised by Oliver E. Sheffield, also of Picatinny Arsenal, for the Engineering Handbook Office of Duke University, prime contractor to the Army Materiel Command.

The Handbooks are readily available to all elements of AMC, including personnel and contractors having a need and/or requirement. The Army Materiel Command policy is to release these Engineering Design Handbooks to other DOD activities and their contractors and to other Government agencies in accordance with current Army Regulation 70-31, dated 9 September 1966. Procedures for acquiring these Handbooks follow:

a. Activities within AMC and other DOD agencies order direct on an official form from:

Commanding Officer Letterkenny Army Depot, ATTN: AMXLE-ATD Chambersburg, Pennsylvania 17201

b. Contractors who have Department of Defense contracts should submit their requests through their contracting officer with proper justification to the address listed in par. a.

c. Government agencies other than DOD having need for the Handbooks may submit their requests directly to the address listed in par. a or to:

Commanding General U. S. Army Materiel Command ATTN: AMCAM-ABS Washington, D. C. 20315

d. Industries not having Government contracts (this includes colleges and Universities) must forward their requests to:

Commanding General U. S. Army Materiel Command ATTN: AMCRD-TV Washington, D. C. 20315

e. All foreign requests must be submitted through the Washington, D. C. Embassy to:

Assistant Chief of Staff for Intelligence Foreign Liaison Office Department of the Army Washington, D. C. 20310

All requests, other than those originating within DOD, must be accompanied by a valid justification.

Comments and suggestions on this handbook are welcomed and should be addressed to Army Research Office-Durham, Box CM, Duke Station, Durham, North Carolina 27706.

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ABBREVIATIONS AND SYMBOLS

~	approximately. This symbol is used before numbers.
AC	Advisory Council on Scientific Research and Develop- ment, Great Britain.
ACS	American Chemical Society.
AISI	American Iron and Steel Institute.
Ann	Liebig's Annalen der Chemie.
Ann chim phys	Annales de chimie et de physique.
AP	armor-piercing.
APG	Aberdeen Proving Ground.
atm	atmosphere; atmospheric pressure.
Beil	Beilstein Organische Chemie, 4th Edition.
Ber	Berichte der Deutschen Chemischen Gesellschaft.
BIOS GP2-HEC	British Intelligence Overseas Service or Objective
	Subcommittee, Group 2, Halstead Exploiting Center.
BM	Bureau of Mines, United States Department of Interior.
Bull Soc chim	Bulletin de la societe chimique de France.
CA	Chemical Abstracts.
calc	calculated.
Chem Met Eng	Chemical and Metallurgical Engineering.
Chim et Ind	Chimie et Industrie.
Comp rend	Comptes rendus hebdomadaires des seances de
	l'Academie des Sciences (Paris).
ср	centipoise.
CR	Comptes rendus hebdomadaires des seances de l'Academie des Sciences (Paris).
dec	decomposes.
∆н	difference in heat (i.e., heat evolved) by decomposition.
DRP	Deutsches Reichspatent.
Е	stress/change in length; (force/area)/(elongation/
F'	same as E, but expressed in $dynes/cm^2$.
Gazz chim ital	Gazzetta Chimica Italiana.
GP	general purpose.
HE	high explosive.
HEAT	high explosive antitank.
Ind Eng Chem	Industrial & Engineering Chemistry.
J Am Chem Soc	Journal of the American Chemical Society
J Chem Ind	The Journal of the Society of Chemical Industry (London).
J Chem Soc	Journal of the Chemical Society (London).
J Frank Inst	Journal of the Franklin Institute.
J Ind Explo-	
sives Soc	Journal of the Industrial Explosives Society (Japan).
J prakt Chem	Journal für praktische Chemie.
LA	lead azide
Land-Bornst	Landolt-Bornstein Physikalish-Chemische Tabellen, 5th Edition (Berlin).
М	molar.
M	Monatshefte für Chemie (Wein).
Mém poudr	Mémorial des poudres et salpêtres (Paris).
mg	milligram.

ABBREVIATIONS AND SYMBOLS (cont'd)

min ml	minimum. millilitor
m/c	militier.
MW	molecular weight
NAVORD	Bureau of Ordnance (II S News)
NG	pitracellulace
D	nitroceriurose.
ⁿ ^D 20	index of refraction, with D band of sodium as light source, at twenty degrees centigrade.
NDRC	National Defense Research Committee.
NFOC	National Fireworks Ordnance Corporation.
NG	nitroglycerin.
NOL	U. S. Naval Ordnance Laboratory, White Oak Silver
	Spring Maryland
NOTS	II S Naval Ordnance Test Station China Lake Calif
NRC	National Research Council
OB	ovvgen balance
OCM	Ordnance Committee Minutes
OSRD	Office of Scientific Research and Development
PA	Dicationy Argonal
DATD	Picatinny Argonal Tashniasl Perent
Phil Tranc	Philosophical Transactions of the Paral Casista of
rnii ilans	London
Pogg Ann	Poggendorf's Annalen der Physik.
Proc Roy Soc	Proceedings of the Royal Society of London.
Rec trav chim	Recueil des travaux chimiques des Pays-Bas.
RH	relative humidity.
RI	Report of Investigation.
SAE	Society of Automotive Engineers.
SAP	semi-armor-piercing.
sol	solution.
Spec	Specifications.
std dev	standard deviation.
тм	Technical Manual, Department of the Army
TM/TO	ioint publication, as a TM and as a Department of the
111, 10	Air Force Technical Order.
Trans Farad Soc	Transactions of the Faraday Society
vac stab	vacuum stability.
Z angew Chem	Zeitschrift für angewandte Chemie.
Z anorg Chem	Zeitschrift für anorganische und allgemeine Chemie.
Z ges Schiess-	Zeitschrift fur das gesamte Schiess und Sprengstoff-
Sprengstoffw	wessen (Munchen).
Z/sec	atoms of oxygen per second.

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PROPERTIES OF EXPLOSIVES OF MILITARY INTEREST

INTRODUCTION

1. PREDOMINANTLY A REPORT OF STANDARD TESTS. No effort was made to cover all the existing literature, either open or classified security information, on any explosive. Rather, the main resource has been reports from facilities using standard or well-known test procedures.

2. ORIGIN. Compilation of data resulting in this handbook was undertaken by Picatinny Arsenal personnel who desired to provide a manual tabulating the characteristics of explosives, based on tests, with regard to current, and possible future, interest. The first resulting Picatinny Arsenal publication was dated 20 June 1949. Revision 1, PA Technical Report No. 1740, dated April 1958, with revisions, provides the data used herein.

<u>3.</u> SCOPE. Tabulated data of tests on one hundred and ten explosive compounds or mixtures include sensitivity to friction, impact, heat; performance characteristics or effectiveness in weapons; physical and chemical properties; and method of preparation, synthesis or manufacture, with comments on historical origin, and supplementary references.

4. REFERENCE NOTATIONS AND SOURCES. The references, as to sources of data or for more details in methods of testing, have been listed, when available, at the end of each section devoted to a given explosive compound, explosive mixture, or explosive ingredient. Where no reference is given, it can be assumed that these data represent typical values obtained by standard procedures. When available any reference should be consulted for more details in interpreting test data.

Also there are listed Picatinny Arsenal Technical Reports which contain additional information on the particular explosive. These report numbers are given in ascending order, in columns corresponding to their terminal digits, and in accordance with the "Uniterm Index" prepared for Picatinny Arsenal by Documentation Incorporated under Contract DAI-36-034-501-ORD-(P)-42 (1955).

5. EXPLANATION OF TERMS AND METHODS OF TESTING. Data are tabulated herein on three form-type pages, in the following sequence of headings. Many of these terms are self-explanatory.

a. First tabular page.

- (1) Name of the explosive in each instance.
- (2) "Composition."
- (3) "Impact Sensitivity, 2 Kg Wt."
 - (a) Impact sensitivity test for solids. (a)*

A sample (approximately 0.02 gram) of explosive is subjected to the action of a falling weight, usually 2 kilograms. A 20-milligram sample of explosive is always used in the Bureau of Mines (BM) apparatus when testing solid explosives. The weight of sample used in the Picatinny Arsenal (PA) apparatus is indicated in each case. The impact test value is the minimum

^{*}Reference publications (a through q), applying to this introduction, are listed at the end of the introduction.

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height at which at least one of 10 trials results in explosion. For the EM apparatus, the unit of height is the centimeter; for the PA apparatus, it is the inch. In the former, the explosive is held between two flat, parallel hardened (C 63 ± 2) steel surfaces; in the latter case, it is placed in the depression of a small steel die-cup, capped by a thin brass cover, in the center of which is placed a slotted-vented-cylindrical steel plug, slotted side down. In the BM apparatus, the impact impulse is transmitted to the sample by the upper flat surface, in the PA, by the vented plug. The main differences between the two tests are that the PA test (1) involves greater confinement, (2) distributes the translational impulse over a smaller area (due to the inclined sides of the die-cup cavity), and (3) involves a frictional component (against the inclined sides).

The test value obtained with the PA apparatus depends, to a marked degree, on the sample density. This value indicates the hazard to be expected on subjecting the particular sample to an impact blow, but is of value in assessing a material's inherent sensitivity only if the apparent density (charge weight) is recorded along with the impact test value. The values tabulated herein were obtained on material screened between 50 and 100 mesh, U. S. Standard Screens where single component explosives are involved, and through 50 mesh for the mixtures.

(b) Impact sensitivity test for liquids. (b)

The PA Impact Test for liquids is run in the same way as for solids. The die-cup is filled and the top of the liquid meniscus adjusted to coincide with the plane of the top rim of the die-cup. To date, this visual observation has been found adequate to assure that the liquid does not wet the die-cup rim after the brass cap has been set in place. Thus far the reproducibility of data obtained in this way indicate that variations in sample size obtained are not significant.

In the case of the BM apparatus, the procedure that was described for solids is used with the following variations:

1. The weight of explosive tested is 0.007-gm.

2. A disc of desiccated filter paper (Whatman No. 1) 9.5-millimeter diameter, is laid on each drop, on the anvil, and then the plunger is lowered on the sample absorbed in the filter paper.

(4) "Friction Pendulum Test." (c)

A 7.0-gm sample of explosive, 50-100 mesh, is exposed to the action of a steel, or fiber, shoe swinging as a pendulum at the end of a long steel rod. The behavior of the sample is described qualitatively to indicate its reaction to this experience, i.e., the most energetic reaction is explosion, and in decreasing order of severity of reaction: snaps, cracks, and unaffected.

(5) "Rifle Bullet Impact Test." (d)

Approximately 0.5-pound of explosive is loaded in the same manner as it is loaded for actual use: that is, cast, pressed, or liquid in a 3-inch pipe nipple (2-inch inside diameter, 1/16-inch wall) closed on each end by a cap. The loaded item, in the standard test, contains a small air space which can, if desired, be filled by inserting a wax plug. The loaded item is subjected to the impact of a caliber .30 bullet fired perpendicularly to the long axis of the pipe nipple, from a distance of 90 feet.

(6) "Explosion Temperature." (a)

A 0.02-gm sample (0.01-gm in the case of initiators) of explosive, loose loaded in a No. 8 blasting cap, is immersed for a short period in a <u>Wood's metal</u> bath. The temperature determined is that which produces explosion, ignition or decomposition of the sample in 5 seconds, and the behavior of the sample is indicated by "Explodes" or "Ignites" or "Decomposes" placed beside the value. Where values were available for times other than 5 seconds, these have been included. For 0.1-second values, no cap was used, but the explosive was placed directly on <u>Wood's metal</u> bath, immediately after cleaning. The value 0.1 second is estimated, not determined, and represents an interval regarded as instantaneous to the observer's eye. Dashes indicate no action.

(7) "75°C International Heat Test." (a)

A 10-gm sample is heated for 48 hours at 75°C. The sample after this exposure is observed for signs of decomposition or volatility.

(8) "100°C Heat Test." (a)

A 0.6-gm sample is heated for two 48-hour periods at 100°C. It is also noted whether exposure at 100°C for 100 hours results in explosion.

(9) "Flammability Index." (h)

The measure of the likelihood that a bare charge will catch fire when exposed to flames is the index of flammability. The test is made by bringing an oxyhydrogen flame to bear on the explosive. The maximum time of exposure which gives no ignition in 10 trials and the minimum exposure which gives ignition in each of 10 trials are determined. The index of flammability is 100 divided by the mean of the two times in seconds. The most flammable substances have high indices, e.g., 250.

(10) "Hygroscopicity."

A 5- to 10-gm sample is exposed for hygroscopicity under the stated conditions, until equilibrium is attained, or in cases where either the rate is extremely low, or very large amounts of water are picked up, for the stated time. The sample, if solid, is prepared by sieving through a 50 and on a 100 mesh screen.

(11) "Volatility."

A 10-gm sample is exposed for volatility under the stated conditions. The sample if solid is prepared by sieving through a 50 and on a 100 mesh sieve.

(12) "Molecular Weight."

The molecular weight (MW) of a mixture can be calculated from the equation

MW of mixture =
$$\frac{100}{\frac{a}{mw_1} + \frac{b}{mw_2} + \frac{c}{mw_3} + \frac{n}{mw_n}}$$

where a, b, c and n are the weight percents of the components, and mw_1 , mw_2 , mw_3 and mw_n their corresponding molecular weights.

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(13) "Oxygen Balance."

The oxygen balance (OB) is calculated from the empirical formula of a compound in percentage of oxygen required for complete conversion of carbon to carbon dioxide (or carbon monoxide) and hydrogen to water. When metal is present the reactions are assumed to occur in the following order:

> Metal + 0 \longrightarrow Metal Oxide C + H₂O \longrightarrow CO + H₂ CO₂ + H₂ \longrightarrow CO + H₂O 2CO + O₂ \longrightarrow 2CO₂

Procedure for calculating oxygen balance is to determine the number of gramatoms of oxygen which are excess or deficient for 100 grams of a compound. This number multiplied by the atomic weight of oxygen gives

the oxygen balance: 1600 (2X + $\frac{Y}{7}$ - Z)

 \div molecular weight of compound = oxygen balance to CO₂ and H₂O, where X = atoms of carbon, Y = atoms of hydrogen, Z = atoms of oxygen. The oxygen balance of a mixture is equal to the sum of the percent composition times the oxygen balance for each component.

The carbon/hydrogen (C/H) ratio is calculated as follows:

Number of C atoms
$$(\%C + \%H)$$
 = C/H ratio
Number of H atoms (100)

(14) "Density."

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- (15) "Melting Point."
- (16) "Freezing Point."
 - (17) "Boiling Point."
 - (18) "Refractive Index."
 - (19) "Vacuum Stability Test." (a)

A 5.0-gm sample (1.0 gm for initiators), after having been carefully dried, is heated for 40 hours, in vacuo at the desired temperature.

(20) "200 Gram Bomb Sand Test."

(a) Sand test for solids. (a)

A 0.4-gm sample of explosive, pressed at 3000 pounds per square inch into a No. 6 cap, is initiated by lead azide, or mercury fulminate (or, if necessary, by lead azide and tetryl), in a sand test bomb containing 200 gm of "on 30 mesh" Ottawa sand. The amount of azide, or of tetryl, that must be used, to insure that the sample crushes the maximum net weight of sand, is designated as its sensitivity to initiation and the net weight of sand crushed, finer than 30 mesh, is termed the sand test value. The net weight of sand crushed is obtained by subtracting from the total the amount crushed by the initiator when shot alone.

(b) Sand test for liquids. (b)

The sand test for liquids is made in accordance with the procedure given for solids except that the following procedure for loading the test samples is substituted:

Cut the closed end from a No. 6 blasting cap and load one end of the resulting cylinder with 0.20 gm of lead azide and 0.25 gm of tetryl, using a pressure of 3000 psi for consolidating each charge. With a pin, prick the powder train in one end of a piece of miner's black powder fuse 8 or 9 inches long. Crimp to the pricked end a loaded cylinder, taking care that the end of the fuse is held firmly against the charge in the cap. Crimp near the mouth of the cap so as to avoid squeezing the charge. Transfer a weighed portion of 0.400 gm of the test explosive to an aluminum cap, taking precautions when the explosive is liquid to insert the sample in such a manner that as little as possible adheres to the side walls of the cap, and when a solid material is being tested use material fine enough to pass through a No. 100 U. S. Standard Sieve. The caps used shall be of the following dimensions: length 2.00 inches, internal diameter 0.248-inch, wall thickness 0.025-inch. Press solid explosives, after insertion into the aluminum cap, by means of hand pressure to an apparent density of approximately 1.2 gm per cubic centimeter. This was done by exerting hand pressure on a wooden plunger until the plunger had entered the cap to a depth of 3.93 centimeters. Following are the dimensions of the interior of the cap: height 5.00 cm, area of cross section 0.312 square centimeters. Insert the cylinder containing the fuse and explosive charge of tetryl and lead azide into the aluminum cap containing the test explosive for the determination of sand crushed.

(21) "Sensitivity to Initiation."

This is sensitivity to initiation as described under the preceding heading. The minimum detonating charge, in grams, required to detonate the explosive sample, is given.

(22) "Ballistic Mortar, % TNT." (e)

The amount of sample under test which is necessary to raise the heavy ballistic mortar to the same height to which it is raised by 10 gm of trinitrotoluene (TNT) is determined. The sample is then rated, on a proportionate basis, as having a certain TNT value, i.e., as being a certain percent as effective as TNT in this respect. The formula is

TNT value =
$$\frac{10}{\text{sample weight}} \times 100$$
.

The ballistic mortar consists of a long compound supporting rod, at the end of which is supported a heavy short-nosed mortar. The mortar contains a chamber about 6 inches in diameter and 1 foot long. A projectile occupies about 7 inches of the chamber and the sample to be tested occupies a small portion of the remainder of the chamber. When the sample is detonated, the projectile is driven into a sand bank, and the mortar swings through an angle which is marked on paper by a pencil attached to the mortar. The angle thus indicates the height to which the pendulum is raised by the explosion, and this latter represents the energy measured by this test procedure.

(23) "Trauzl Test, % TNT." (d)

A sample of the explosive to be tested (of the order of 10 gm) is exploded in a cavity, or borehole, 25-mm in diameter and 125-mm deep, in a lead block 200-mm in diameter and 200-mm in height. The borehole is made centrally in the upper face of each block, which is cast in a mold from desilverized lead of the best quality. Although these tests have been made under a variety of conditions, where possible the data have been taken from or related to those of Reference f (Naoum). Here a No. 8 blasting cap was used for initiation of the sample contained in glass. The weight of sample used was adjusted to give, with the initiator, a total expansion of 250 to 300 cc, since within this range expansion and sample weight were linearly related under the conditions of Naoum's test. Thus expansions for equivalent weights were readily calculated, and the test value expressed in percent of the expansion of an equivalent weight of TNT.

(24) "Plate Dent Test." (d)

Two methods were used for plate dent tests.

(a) Method A - The charge is contained in a copper tube, having an internal diameter of 3/4-inch and 1/16-inch wall. This loaded tube is placed vertically on a square piece of cold-rolled steel plate, 5/8-inch thick; 4-inch and 3-1/4-inch square plate gave the same results. The steel plate is in a horizontal position and rests in turn on a short length of heavy steel tubing 1-1/2 inches ID and 3 inches OD. The charge rests on the center of the plate, and the centers of the charge, plate, and supporting tube are in the same line. A 20-gm charge of the explosive under test is boostered by a 5-gm pellet of tetryl, in turn initiated by a No. 8 detonator.

(b) Method B - A 1-5/8-inch diameter, 5-inch long uncased charge is fired on a 1-3/4-inch thick, 5-square inch cold-rolled steel plate, with one or more similar plates as backing. The charge is initiated with a No. 8 detonator and two 1-5/8-inch diameter, 30-gm tetryl boosters.

Plate dent test value, or relative brisance = $\frac{\text{Sample Dent Depth}}{\text{Dent Depth for TNT at 1.61 gm/cc}} \times 100.$

(25) "Detonation Rate." (g)

The detonation rates reported in the tables contained herein were determined principally by using the rotating drum camera, under the conditions stated, e.g., usually charges 1 inch in diameter, 20 inches long, wrapped in cellulose acetate sheet, and initiated by a system designed to produce high order stable detonation at the maximum rate under the particular conditions. A typical initiating system for this consisted of four tetryl pellets 0.995 inch in diameter, 0.75 inch long, pressed to 1.50 gm/cc, with a Corps of Engineers special blasting cap placed in a central hole in the end pellet.

b. Second tabular page.

6

(1) "Booster Sensitivity Test." (p)

The booster sensitivity test procedure is a scaled up modification of the Bruceton method (unconfined charge). The source of the shock consists of two tetryl pellets, each 1.57 inches diameter by 1.60 inches high, of approximately 100 gm total weight. The initial shock is degraded through wax spacers of cast Acrawax B, 1-5/8 inches diameter. The test charges are 1-5/8 inches diameter by 5 inches long. The value given is the thickness of wax in inches at the 50% detonation point. The weight of tetryl pellet noted is the minimum which will produce detonation with the spacer indicated.

(2) "Heat of" (calorimetric tests). (i)

Heats of combustion and explosion are generally determined on samples weighing of the order of 1 to 2 gm, in standard calorimeter bombs such as the Parr or Emerson, approximately 400 cc (for low loading density), or the Boas, approximately 45 cc (for high loading density). For

heats of combustion the sample is burned under about 40 atmospheres of oxygen; for heats of explosion, nitrogen, or one atmosphere of air is used.

- (3) "Specific Heat."
- (4) "Burning Rate."
- (5) "Thermal Conductivity."
- (6) "Coefficient of Expansion."
- (7) "Hardness, Mohs' Scale."
- (8) "Young's Modulus."
- (9) "Compressive Strength."
- (10) "Vapor Pressure."
- (11) "Decomposition Equation."
- (12) "Armor Plate Impact Test." (j)
 - (a) 60-mm Mortar Projectile.

A modified 60-mm, M49A2, mortar projectile is loaded with the explosive to be tested, drilled to the proper depth (about 1/2 inch), and a flat-based steel plug screwed into the projectile to give a smooth close-fit between the plug base and the charge. The part of the plug outside the projectile is rounded off in the form of a spherical section. The loaded projectile with fins attached is fired from a five foot length of 2-3/8 inches ID x 3-3/8 inches OD Shelby steel tubing. The igniter and propelling charge, consisting of an igniter for a 2.36-inch rocket (bazooka), 5 gm of 4F black powder, and a quantity of shotgun propellant sufficient to give the desired velocity (read from a calibration chart) are conveniently loaded into the "gun" through a simple breech plug. The velocities are measured electronically, and the reaction, inert or affected, is determined by observation (e.g., whether or not flash occurs on impact). Within the range of flight stability of the projectile, 200-1100 ft/sec, the 50% point is located.

- (b) 500-1b General Purpose Bombs.
- (13) "Bomb Drop Test."

Bomb drops are made using bombs assembled in the conventional manner, as for service usage, but containing either inert or simulated fuzes. The target is usually reinforced concrete.

c. Third tabular page.

(1) "Fragmentation Test." (1)

The weight of each empty projectile and weight of water displaced by the explosive charge is determined, and from this the specific gravity of the charge is calculated. All 3-inch and 90-mm projectiles are initiated by M2O Booster pellets, and those used with 3-inch HE, M42Al, Lot KC-5 and 90-mm HE, M71, Lot WC-91 projectiles are controlled in weight and height as follows: 22.50 + 0.10 gm, and 0.480 to 0.485 inch.

The projectile assembled with fuze, actuated by a Blasting Cap, Special, Type II (Spec 49-20) placed directly on a lead of comparable diameter, and booster, are placed in boxes constructed of half-inch pine. The 90-mm projectiles are fragmented in boxes $21 \times 10-1/2 \times 10-1/2$ inches and the 3-inch projectiles in boxes $15 \times 9 \times 9$ inches outside dimensions. The box with projectile is placed on about 4 feet of sand in a steel fragmentation tub, the detonator wires are connected, and the box covered with approximately 4 feet more of sand. The projectile is fired and the sand run onto a gyrating 4-mesh screen on which the fragments are recovered.

(2) "Fragment Velocity."

Charges 10-1/8 inches long and 2 inches in diameter, containing a booster cavity, filled by a 72-gm tetryl pellet (1-3/8 inches diameter, 2 inches long, average density 1.594) are fired in a model projectile of Shelby seamless tubing, 2 inches ID, 3 inches OD, SAE 1020 steel, with a welded-on cold rolled steel base. The projectile is so fired in a chamber, connected to a corridor containing velocity stations, that a desired wedge of projectile casing fragments can be observed. The fragment velocities are determined by shadow photographs, using flash bulbs, and rotating drum cameras, each behind three slits. The drum cameras have a writing speed of 30 meters per second.

(3) "Blast (Relative to TNT)."

The blast pressures and impulses given were determined almost exclusively with tourmaline gages, and the usual necessary specialized electrical circuits, shielded co-axial cables, oscillographs, etc. In general, the data represent results of tests with large cased charges.

(4) "Shaped Charge Effectiveness, INT = 100." (k, m)

Unconfined charges 2 inches in diameter and 6 inches long, boostered by a 10-gm pressed tetryl pellet, set in a 20-mm pellet (truncated cone) of cast 60/40 cyclotol, are shot against 3-inch homogeneous armor plate at a 1-3/16 inches standoff. The cones used are commercial Pyrex glass funnels, sealed off at the start of the stem, 2 inches in diameter, 0.110 to 0.125 inch wall thickness.

Unconfined charges 1.63 inches in diameter and 6 inches long are tested at a standoff of 1.63 inches against stacks of $4 \times 4 \times 1$ inch mild steel plates. M9Al steel cones are used. Results are averages of 4 trials.

- (5) "Color."
- (6) "Principal Uses."
- (7) "Method of Loading."
- (8) "Loading Density."
- (9) "Storage."

Ammunition and bulk explosives in storage represent varying degrees of hazard and compatibility. This has led to their being divided into a number of hazard classes and compatibility groups as indicated in subparagraphs (b) and (c) below.

- (a) Method: Wet or dry.
- (b) Hazard Class (Quantity-Distance).

Ammunition and bulk explosives are divided into quantity-distance classes, Class 1 through 12, according to the damage expected if they explode or ignite (Reference: Army Materiel Command Regulation, AMCR 385-100, AMC Safety Manual, chapter 17). All standard explosives in bulk are included in four of these classes: Class 2, 2A, 9, and 12 (TM 9-1910/TO 11A-1-34).

(c) Compatibility Group.

Explosives and ammunition are grouped for compatibility with respect to the following factors:

- 1. Effects of explosion of the item.
- 2. Rate of deterioration.
- 3. Sensitivity to initiation.
- 4. Type of packing.
- 5. Effects of fire involving the item.
- 6. Quantity of explosive per unit.
- (d) Exudation.

d. Miscellaneous entries.

Where available and appropriate, the following or related data are given, in space at the bottom of the third form, or on plain pages.

- (1) Solubility.
- (2) Methods of manufacture.
- (3) Historical information.
- (4) Bulk compressibility modulus. (q)

The direct experimental measurement of the dynamic bulk modulus of a solid is difficult, and few such measurements have been made. One apparatus has been developed at the Naval Ordnance Laboratory and is described in detail in Reference q. Bulk modulus (its reciprocal is the compressibility) is defined as the ratio of stress to strain when the stress is a pressure applied equally on all surfaces of the sample and the strain is the resulting change in volume per unit volume.

(5) Hydrolysis tests. (0)

The 240-hour hydrolysis test is conducted as follows: A 5-gm sample of the dry nitrocellulose is weighed accurately in a tare-weighed 250-cc Pyrex flask having a ground glass connection for a Pyrex condenser. Then 100 cc of distilled water is added to the nitrocellulose in the flask and the flask fitted to the condenser. The flask is placed in a steam bath in which the water is kept boiling constantly by means of electric hotplates. At the end of 240 hours the amount of solid developed by the hydrolysis of the nitrocellulose is measured by an electromatic pH method.

(6) Sensitivity to initiation by electrostatic discharge. (n)

9

The samples are tested under two amounts of confinement, designated as unconfined and confined. In the unconfined test, a sample of approximately 0.05 gm is dumped into a shallow depression in a steel block and flattened out with a spatula. In the confined tests (partly confined), the sample of approximately 0.05 gm is introduced into soft-glass tube ($\sim 7 \text{ mm ID x}$ 18 mm long) which fits over a metal peg. The volume of the space around the charge at zero gap is ~ 0.15 cc; at a gap of 0.6 mm, it is ~ 0.4 cc. In addition to providing moderate confinement, this system also minimizes dispersion of the sample by the test spark, and reduces the effect of material being repelled from the needle point by electrostatic field effect.

When a test is to be made, the needle point electrode is screwed up until the gap between electrodes is greater than the critical gap discharge at the test voltage. The sample is then placed in position, the high-voltage terminal of the charged condensor is switched to the point electrode by means of a mercury switch, and the electrode is screwed down until discharge occurs.

The spark energy (in joules), for zero probability of ignition, is determined.

(7) Destruction by chemical decomposition.

Burning is the preferred method of destroying explosives. Initiating type explosives (in quantity) are usually destroyed by detonation with demolition blocks. Destruction of explosives by chemical decomposition can be effectively used where small laboratory quantities are involved. Procedures given are standard for only lead azide, mercury fulminate and nitrogly-cerin.

- (8) Other information.
- (9) References.

6. REFERENCES CITED IN INTRODUCTION.¹

a. W. H. Rinkenbach and A. J. Clear, Standard Laboratory Procedures for Sensitivity, Brisance, and Stability of Explosives, PATR No. 1401, 18 March 1944, Revised 28 February 1950.

b. W. R. Tomlinson, Jr. and A. J. Clear, <u>Development of Standard Tests</u> -- Application of the Impact and Sand Tests to the Study of Nitroglycerin and Other Liquid Explosives, PATR No. 1738, 13 June 1949.

c. J. H. McIvor, Friction Pendulum, PA Testing Manual 7-1, 8 May 1950.

d. Departments of the Army and the Air Force Joint Technical Manual and Technical Order, TM 9-1910/TO 11A-1-34, Military Explosives, April 1955.

e. J. H. McIvor, Ballistic Mortar Test, PA Testing Manual 7-2, 8 May 1950.

f. Ph. Naoum, Z ges Schiess-Sprengetoffw, pp. 181, 229, 267 (27 June 1932).

g. G. J. Mueller, Equipment for the Study of the Detonation Process, PATR No. 1465, 4 July 1945.

h. NDRC Interim Report, <u>Preparation and Testing of Explosives</u>, Nos. PT-19 and PT-20, February-April 1944.

i. Linnie E. Newman, PA Chemical Laboratory Report Nos. 127815 and 134476, 11 January 1951.

j. Report AC-2983/Org Expl 179.

¹For information regarding source of references, inquiries should be made to the Commander, U.S. Army Research Office--Durham, ATTN: CRDARD-EH, Box CM, Duke Station, Durham, North Carolina 27706.

k. Eastern Laboratory, du Pont, Investigation of Cavity Effect, Section III, Variation of Cavity Effect with Composition, NDRC Contract W-672-ORD-5723.

1. J. H. McIvor, Fragmentation Test Procedures, PA Testing Manual 5-1, 24 August 1950.

m. Eastern Laboratory, du Pont, <u>Investigation of Cavity Effect</u>, Final Report, 18 September 1943, NDRC Contract W-672-ORD-5723.

n. F. W. Brown, D. H. Kusler, and F. C. Gibson, <u>Sensitivity of Explosives to Initiation</u> by Electrostatic Discharges, U. S. Department of Interior, Bureau of Mines, R. I. 3852, 1946.

o. D. D. Sager, Study of Acid Adsorption and Hydrolysis of Cellulose Nitrate and Cellulose Sulphate, PATR No. 174, 12 January 1932.

p. L. C. Smith and E. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report No. 5746, 27 December 1945.

q. C. S. Sandler, An Acoustic Technique for Measuring the Effective Dynamic Bulk Modulus of Elasticity and Associated Loss Factor of Rubber and Plastics, NAVORD Report No. 1524, 1 September 1950.

W. S. Cramer, <u>Bulk Compressibility Data on Several Explosives</u>, NAVORD Report No. 4380, 15 September 1956.

Composition:		Molecular Weight:	anna Chaillean mailte stàitea	92	
70 Ammonium Nitrate INT	80 20	Oxygen Balance: CO ₂ % CO %		+1 +11	
		Density: gm/cc Cast	; 1	.46	
		Melting Point: "C		abern in	
C/H Ratio		Freezing Point: °C	a. Serie at	10 . E. S.	_
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C			
Sample Wt 20 mg Picatinny Arsenal Apparatus, ir Sample Wt, mg	n. 15 17	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	an rain an an rain an rain an an an an an an an an	Anna Anna Maria Maria Anna Anna Anna Maria Maria	
Friction Pendulum Test:		Vacuum Stability Test:		A CONTRACTOR	-
Steel Shoe Unafi Fiber Shoe Unafi	fected fected	cc/40 Hrs, at 90°C			
Rifle Bullet Impact Test: 5 Trial	s	100°C	0	.45	
%		120°C	0.	•95	
Explosions 0		135°C	6	8	
Partials 0			0.	.0	
Burned 0		200 Gram Bomb Sand Test:			
Unaffected 100		Sand, gm	35	•5	
Explosion Temperature: ° Seconds, 0.1 (no cap used)	с	Sensitivity to Initiation: Minimum Detonating Charg	je, gm		
5 Decomposes 280)	Lead Azide	0	20	
10		Tetryl	0	.07	
15					
20		Ballistic Mortar, % TNT: (a) 13	30	
		Trauzi Test, % TNT: (b) 12	23	
 75°C International Heat Test: % Loss in 48 Hrs 	0.06	Plate Dent Test: Method			
100°C Heat Test:		Condition			
% Loss, 1st 48 Hrs	0.03	Confined			
% Loss, 2nd 48 Hrs	0.05	Density, gm/cc			
Explosion in 100 Hrs	None	Brisance, % TNT			
Flammability Index:		Detonation Rate: Confinement	None	None	
Hvaroscopicity: %		Condition	Cast	Cast	
30°C, 90% RH, 2 days	61	Charge Diameter, in.	1.0	1.0	
Volatility:	Nil	Density, gm/cc	1.40	1.50	
		Rate, meters/second	4500	5100	

Amatol, 80/20

Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100:
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones Steel Cones
Density, gm/cc	Hole Volume
Charge Wt. Ib	Hole Depth
charge trip is	in the second
Total No. of Fragments:	Color: Buff-yellow
For TNT	
For Subject HE	Principal Uses: Bombs, HE projectiles
3 inch HE, M42A1 Projectile, Lot KC-5:	and under a second s
Density, gm/cc	
Charge Wt, Ib	Footness Particulation in 1997
Total No. of Fragments:	Method of Loading: Cast
For TNT	visitan Conductor Tests
For Subject HE	
	Loading Density: gm/cc 1.46
Fragment Velocity: ft/sec	f)
At 9 ft 1	900
At 251/2 ft 1	750 Storage:
Density, gm/cc	Ad-al-
	Method
Blast (Relative to TNT):	Hazard Class (Quantity-Distance) Class 9
	Compatibility Group Group I
Air:	
Peak Pressure	Exudation Does not exude at 65°C
Impulse	
Energy	
Air Confined:	Booster Sensitivity Test: (a)
Impulse	and a statistic
	Condition Pressed
Under Water:	Wax, in. for 50% Detonation 0.83
Peak Pressure	Density, gm/cc 1.65
Impulse	
Energy	Heat OI: (d, e)
	Combustion, cal/gm 1002*
Underground:	Explosion, cal/gm 490*
Peak Pressure	Gas Volume, cc/gm 930*
Impulse	
Energy	the second se
	*Calculated from composition of mixture.
	Current con row composition of minor of

Composition:	Molecular Weight:	108
Ammonium Nitrate 60 TNT 40	Oxygen Balance: CO ₂ % CO%	-18 + 2
	Density: gm/cc Cast	1.60
	Melting Point: °C	PARTY AND
C/H Ratio	Freezing Point: °C	H majikat nati
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	Aller and the second of
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 16 Sample Wt, mg 17	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	Charaity, grown y, Charaity, grown y, gr
Friction Pendulum Test:	Vacuum Stability Test:	WIT with
Steel Shoe Fiber Shoe	cc/40 Hrs, at 90°C	
Rifle Bullet Impact Test: Trials	100°C	
%	120°C	
Explosions	135°C	
Partials	150°C	
Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm	41.5
Explosion Temperature: °C C Seconds, 0.1 (no cap used)	Sensitivity to Initiation: Minimum Detonating Charge, gm	Addi Pasile Program
article is delived were associated in a trade	Mercury Fulminate	
5 Decomposes 270	Lead Azide	0.20
10	Tetryl	0.06
20	Ballistic Mortar, % TNT: (a)	128
Link	Trauzl Test, % TNT:	Chatter Worker
75°C International Heat Test:% Loss in 48 Hrs	Plate Dent Test: Method	Pennana Projective
100°C Heat Test:	Condition	vp sead
% Loss, 1st 48 Hrs	Confined	
% Loss, 2nd 48 Hrs	Density, gm/cc	Dadwiggeneral :
Explosion in 100 Hrs	Brisance, % TNT	interest and a second
Flammability Index:	Detonation Rate: Confinement	None
Hyproscopicity: %	Condition	Cast
Trygroscopicity: 70	Charge Diameter, in.	1.0
Volatility: Ni 1	Density, gm/cc	1.50
,, ,, ,, ,, ,, ,, ,, ,, ,, ,, ,, ,, ,,	Rate, meters/second	5760

Amatol, 60/40

Fragmentation Test:		Shaped Charge Effectiveness, TNT = 100:
90 mm HE, M71 Projectile. Lot	WC-91;	Glass Cones Steel Cones
Density am/cc	1.49	Hole Volume
Charge Wt Ib	1.971	Hole Depth
Charge With 15		
Total No. of Fragments:		Color: Buff wellow
For TNT	703	Bull-yellow
For Subject HE	583	Principal Uses: Bombs, HE projectiles
3 inch HE, M42A1 Projectile, Lo	t KC-5:	and a second second second second second second
Density, gm/cc	1.57	
Charge Wt, Ib	0.827	Prodimer Assessor Appandes Inc. 20
Total No. of Fragments:		Marked of Londing: Cast
For TNT	514	Mernoa or Loading; Cast
For Subject HE	408	Construction of the second
For Subject FIL	191 191 194 194 194 194 194 194 194 194	Loading Density: gm/cc 160
Fragment Velocity: ft/sec	51091	
At 9 ft		Storage:
Density am/cc		building and a second
Density, gin/ cc		Method Dry
Blast (Relative to TNT):	Det Book famor 2004	Hazard Class (Quantity-Distance) Class 9
		Compatibility Group Group I
Air: Deck Pressure	95	
Impulse	85	Exudation Does not exude at 65°C
Energy	84	PHS, improving at 1
Energy	1000	
Air. Confined:		Heat OI: (a, e)
Impulse		Combustion, cal/gm 1658*
Under Water:		Gas Volume, cc/gm 880*
Peak Pressure		1 C foreinnithmail Arad Table
Impulse		
Energy		
Underground:		
Peak Pressure		
Impulse		
Energy		the second s
		Albour Aurichismi
		*Calculated from composition of mixture.

Composition:	Molecular Weight:	118
Ammonium Nitrate 50 INT 50	Oxygen Balance: CO ₂ % CO %	-27 - 3
	Density: gm/cc Cast	1.59
wall have fittee the second second	Melting Point: °C	
C/H Ratio	Freezing Point: °C	He Trought & And
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	8 × 1944 (201 april 0
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 16 Sample Wt, mg 17	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	t a los la Depoises surres en Elegense V ^{er} Redekteres of Anom
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C	1991 Sectors (1997) Sectors (1997)
Rifle Bullet Impact Test: Trials	- 100°C	0.2
%	120°C	1.0
Explosions 0	135 C	
Partials 0	150 €	
Burned 0 Unaffected 100	200 Gram Bomb Sand Test: Sand, gm	42.5
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 265	Sensitivity to Initiation: Minimum Detonating Charge, gn Mercury Fulminate	
10		0.20
15		0.0)
20	Ballistic Mortar, % TNT: (a)	124
- AL REAL REAL REAL	Trauzl Test, % TNT:	A DESCRIPTION OF THE OWNER
 75°C International Heat Test: % Loss in 48 Hrs 	Plate Dent Test: Method	B schemet
100°C Heat Test:	Condition	Cast
% Loss, 1st 48 Hrs	Confined	No
% Loss, 2nd 48 Hrs	Density, gm/cc	1.55
Explosion in 100 Hrs	Brisance, % TNT	52
Flammability Index:	- Detonation Rate: Confinement None	e None
Hygroscopicity: % Nil	Condition Cast Charge Diameter, in. 1.0	L Cast 1.0
Volatility:	Density, gm/cc 1.55 Rate, meters/second 6430	5 1.55 6230

Amatol, 50/50

Fragmentation Test:		Shaped Charge Effectiveness, TNT $=$ 100:	1923 -
90 mm HE, M71 Projectile, Lot	WC-91:	Glass Cones Steel Cones (g)	
Density, gm/cc	1.55	Hole Volume 53	
Charge Wt, Ib	2.053	Hole Depth 69	
Total No. of Fragments:		Color: Buff-yellow	
For TNT	703	be a sidulfunction that is not the set of a second with the	
For Subject HE	630	Principal Uses: Bombs, HE projectiles	
3 inch HE, M42A1 Projectile, Lot	KC-5:		
Density, gm/cc	1.54		
Charge Wt, Ib	0.819		
Total No. of Fragments:		Method of Loading: Cast	
For TNT	514		
For Subject HE	385		
		Loading Density: gm/cc 1.59	
Fragment Velocity: ft/sec At 9 ft At 25½ ft		Storage:	
Density, gm/cc		And the second s	
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy	97 87	Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation Does not exude at 65°C	
Air, Confined: Impulse		Booster Sensitivity Test:(a)ConditionCastTetryl, gm100Wax, in. for 50% Detonation0.60Density, gm/cc1.55	
Under Water: Peak Pressure		Heat of: (d, e)
Impulse		Combustion, cal/gm 1990 Explosion cal/gm 702*	
Energy	98	Gas Volume, cc/gm 855*	
Underground: Peak Pressure	104 104	*Calculated from composition of mixture. <u>Specific Heat: cal/gm/^OC</u> (i) <u>Temp, 20^o to 80^oC</u> 0.383	3
r .	104	Bomb Drop Test.	
Energy	104	T7, 2000-1b Semi-Armor-Piercing Bomb vs Concrete:	
		Max Safe Drop, ft 4000-500	0

Compatibility with Metals:

Dry - Metals unaffected are zinc, iron, tin, brass, brass tin plated, brass NRC coated, brass shellac coated, nickel aluminum, steel, steel plated with nickel, zinc or tin, stainless steel, Parkerized steel, and steel coated with acid-proof black paint. Metals slightly affected are copper, bronze, lead and copper plated steel.

Preparation:

In preparing amatols the proper granulation of ammonium nitrate is required if the maximum density of the cast amatol is desired. The ammonium nitrate should be dried so as to contain not more than 0.25% moisture. It should be heated to about 90°C before being added to the appropriate weight of molten TNT contained in a melting vessel equipped with an agitator. Continue mixing to insure uniformity and load by pouring into shell or bombs.

Origin:

Developed by the British during World War I in order to conserve TNT.

References: 2

(a) L. C. Smith and E. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report 5746, 27 December 1945.

(b) Report AC-17/Phys Ex 1.

(c) D. P. McDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

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(d) Committee of Div 2 and 8, NDRC, <u>Report on HBX and Tritonal</u>, OSRD Report No. 5406, 31 July 1945.

(e) Philip C. Keenan and Dorothy Pipes, <u>Table of Military High Explosives</u>, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(f) R. W. Drake, Fragment Velocity and Panel Penetration of Several Explosives in Simulated Shells, OSRD Report No. 5622, 2 January 1946.

(g) Eastern Laboratory, du Pont, <u>Investigation of Cavity Effect</u>, Final Report, 18 September 1943, NDRC Contract W-672-ORD-5723.

(h) Also see the following Picatinny Arsenal Technical Reports on Amatols:

<u>o</u>	<u>1</u>	2	<u>3</u>	<u>4</u>	<u>5</u>	6	<u>7</u>	8	2
240 350 630 950 1300 1530	681 731 901 1051 1311 1451 1651	132 182 1302 1352 1372 1552	743 1173 1373 1323 1493 1783	364 694 734 874 1344	65 425 695 715 1145 1225 1345 1455 1885	266 556 986 1376 1446 1636 1796	1207 1457 1797 1827 2167	548 638 838 1098 1148 1388 1568 1838	549 799 929 1129 1219 1369 1559

(i) TM 9-1910/TO 11A-1-34, Military Explosives, April 1955.

²See footnote 1, page 10.

Ammonal

Composition:	Strend Corner	Molecular Weight:	102
% Ammonium Nitrate INT Aluminum	22 67	Oxygen Balance: CO ₂ % CO %	-55 -22
ATAIITHAII	- 10 - 10	Density: gm/cc Cast	1.65
		Melting Point: °C	a to all the T
C/H Ratio		Freezing Point: °C	anna an t
Impact Sensitivity, 2 Kg Wt:	01	Boiling Point: °C	
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	91 11 19	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	territi grafi Reinan Mita B
Friction Pendulum Test:	albert in fantsen	Vacuum Stability Test:	Turter
Steel Shoe Fiber Shoe		cc/40 Hrs, at 90°C	
	There are a subsection of	100°C	
Rifle Bullet Impact Test: Trials		120°C	4.4
Explosions		150°C	
Burned		200 Gram Bomb Sand Test:	
Unaffected		Sand, gm	47.8
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 265 10	Concernations Technics	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	0.20
20		Ballistic Mortar, % TNT: (a)	122
	Influine produced	Trauzl Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs		Plate Dent Test: Method	anti se anti-
100°C Heat Test:		Condition	
% Loss, 1st 48 Hrs	0.00	Density am/cc	
% Loss, 2nd 48 Hrs	0.10 None	Brisance, % TNT	
	110116	Detonation Rate:	and the second second
Flammability Index:		Confinement	
Hygroscopicity: %		Condition Charge Diameter, in.	
Volatility:		Density, gm/cc Rate, meters/second	

AMCP 706-177

Ammonal

Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100:
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones Steel Cones
Density, gm/cc	Hole Volume
Charge Wt, Ib	Hole Depth
Total No. of Fragments:	Color:
For TNT	
For Subject HE	Principal Uses: Projectile filler
3 inch HE M4241 Projectile Lat KC-5:	Thick pulled
Density am/cc	. 65
Charge Wt. Ib	Bushops, Adversive a property of the
Charge Wit, ib	
Total No. of Fragments:	Mathed of Logding: Cost
For TNT 6	55 manual defined of Loading. Cast
For Subject HE 5	50
	Loading Density: gm/cc 1.65
Fragment Velocity: ft/sec	Luits Faller In-Lord Tours. They
At 9 ft At 251/2 ft	Storage:
Density, am/cc	2 (A)
	Method Dry
- A BOARD AND A CONTRACT OF	Henced Class (Quantity Distance) Class 9
Blast (Relative to TNT):	Hazara Class (Quantity-Distance)
A	Compatibility Group
Peak Pressure	stationales - a second dell'indiane de la second de la secondade ;
Impulse	Exudation
Energy	
	Origin:
Air, Confined:	Castable mixture developed in United States
	during World War I.
Under Water:	References.
Peak Pressure	(a) U D Marlinson In Division and Fr
Impulse	plosive Properties of Military Explosives.
Energy	PATR No. 1372, 29 November 1943.
Underground:	(b) Also see the following Picatinny Ar-
Peak Pressure	senal Technical Reports on Ammonals: 1108,
Impulse	1286, 1292, 1308 and 1783.
Energy	Flageneichtry Johns
Preparation:	
Procedure same as described un	der Amatols,
except aluminum is added to the a trate-INT molten mixture under ag til uniformity in composition is	ummonium ni- itation un- obtained. mg into the

Composition:	Molecular Weight: $(\mathbb{H}_{4}\mathbb{N}_{2}^{0})$	80	
N 35	Oxygen Balance: CO ₂ % CO %	+20 +20	
in 5 militario 3	Density: gm/cc Crystal	1.73	
0 60	Melting Point: °C	170	
C/H Ratio	Freezing Point: °C	alife sectors	
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	and an and an	
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 31 Sample Wt, mg 17	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	na line est anno 1	
Friction Pendulum Test:Steel ShoeUnaffectedFiber ShoeUnaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C		
Rifle Bullet Impact Test: Trials		0.3	
%	120°C	0.3	
Explosions 0	150°C	0.3	
Partials 0 Burnad 0			
Unaffected 100	Sand, gm	Nil	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 465 10	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	0.20 0.25	
20	Ballistic Mortar, % TNT: (a)	56	
turn (Inter-	Trauzi Test, % TNT:	and the second	
75°C International Heat Test: (a) % Loss in 48 Hrs 0.0	Plate Dent Test: Method	 Provident Press Provident Press 	
100°C Heat Test:	Condition		
% Loss, 1st 48 Hrs 0.74	Confined		
% Loss, 2nd 48 Hrs 0.13	Density, gm/cc Brisonce % TNT		
Explosion in 100 Hrs None			
Flammability Index:	Detonation Rate: (b) Confinement None Condition Solid	Strong	
Hygroscopicity: % 30 ^o C, 90% RH Extreme	Charge Diameter, in. 1.25	4.5	
Volatility: Decomposes at 210 ⁰ C	Rate, meters/second 1000	2500	

Booster Sensitivity Test: Condition	f., stal W adapticht	Decomposition Equation: (: Oxygen, atoms/sec	f) (h) 1012.3
Tetryl, gm		(Z/sec)	10 5 28 2
Wax, in. for 50% Detonation		(ΔH, kcal/mol)	40.7 50.5
Wax, gm		Temperature Range, °C	243-261 217-267
Density, gm/cc		Phase	Liquid
Heat of:	2):6	Armor Plate Impact Test:	
Compussion, cal/gm	340		
Explosion, cal/gm	980	60 mm Mortar Projectile:	 A second sec second second sec
Gds volume, cc/gm	1008	50% Inert, Velocity, ft,	sec
Formation, cal/gm	1090	Aluminum Fineness	
Fusion, cal/gm	10.53	500 Ib Ganaral Burnara Ba	and the second
· · · · · · · · · · · · · · · · · · ·	(0)	Soo-ib General Purpose bo	inds:
og og	(e)	Plate Thickness, inches	
	0.007		
-100 0.330 50	0.414	1	
-50 0.364 100	0.428	11/4	
		11/2	
		13/4	
Burning Rate:			
cm/sec		Bomb Drop Test:	Sec. 1
Thermal Conductivity:	an shire sheet. Mana sije	-	
cal/sec/cm/°C 2.9-3.9 x	: 10 ⁻⁴	T7, 2000-Ib Semi-Armor-P	Piercing Bomb vs Concrete:
Coefficient of Expansion:		- Max Safe Drop, ft	
Linear, %/°C		500-1b General Purpose B	omb vs Concrete:
Volume, %/°C	1000 C - 100	Height, ft	
		- Trials	
Hardness, Mohs' Scale:		Unaffected	
	Way to the ballout	Low Order	
Young's Modulus:		High Order	
E', dynes/cm ²		(15 g	
E, Ib/inch ²		1000-lb General Purpose B	Somb vs Concrete:
Density, gm/cc			
	* Martha Mart	– Height, ft	
Compressive Strength: Ib/inch ²		Trials	
	UKT , jama julij	Unaffected	
Vapor Pressure: (g)		Low Order	
°C mm Mercu	Jry	High Order	
188 3.25			
205 7.45		per projecti	Approximate (Provide Approximate A Approximate Approximate Approxi
223 15.80		1 Mar Thursday Barbary Spreak 1 1	
237 27.0			

Fragmentation Test:	Shaped Charge Effectiveness, $TNT = 100$:
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Cones Hole Volume Hole Depth
Total No. of Fragments: For TNT	Color: Colorless
For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib	Principal Uses: Explosive ingredient of mixtures used in bombs or large caliber projectiles
Total No. of Fragments: For TNT For Subject HE	Method of Loading: Pressed or cast dependin on composition of mixture
and the state of a state of the	Loading Density: gm/cc Variable
ragment Velocity: ft/sec At 9 ft At 25½ ft	Storage:
Density, gm/cc	Method Dry
last (Relative to TNT):	Hazard Class (Quantity-Distance) Class 12
Air: Peak Pressure	Compatibility Group Group D
Impulse	Exudation None
Energy Air, Confined: Impulse	Effect of Temperature on Impact Sensitivity (Chemically pure grade): (b)
Under Water: Peak Pressure	Temp. PA Impact Test <u>OC</u> <u>2 Kg Wt, inches</u> 25 31
Impulse Energy	75 28 100 27 150 27
Underground: Peak Pressure	Compatibility with Metals: (a)
Impulse Energy	In the presence of moisture, ammonium nitrate reacts with copper, iron steel, brass, lead and cadmium.
	Entropy: (g)

Wa	ter	Alc	ohol	Acet	ic Acid		Nitric	Acid	Pyr	ridine
о <u>с</u> 20 20 40 60 80	7 118 192 297 421 580	о _с 20 40 60 78	2.5 5 7.5 10.5	°c 16.6 27.0 80.9 101.0 120.0	0.0 0.39 5.8 20.7 125	°c 0 15 30 75	45.1 73.0 106 201	<u>Acid</u> 30.0 21.7 20.8 31.6	°c 25	~ 2 0-2 5

Solubility of ammonium nitrate, grams in 100 grams (%) of: (e)

Preparation:

Ammonium nitrate is prepared by the neutralization of an aqueous solution of ammonia with nitric acid and evaporation of the solution. The product which is very pure is dried in a graining kettle.

Origin:

First prepared by Glauber in 1659 and first used as an explosive ingredient in 1867 when a Swedish patent was granted to Ohlsson and Norrbin for a composite dynamite.

Destruction by Chemical Decomposition:

Ammonium nitrate is decomposed by strong alkalies with the liberation of ammonia, and by sulfuric acid with the formation of ammonium sulfate and nitric acid.

References: 3

(a) Departments of the Army and the Air Force TM 9-1910/TO 11a-1-34, Military Explosives, April 1955.

(b) P. F. Macy, T. D. Dudderar, E. F. Reese and L. H. Eriksen, Investigation of Sensitivity of Fertilizer Grade Ammonium Nitrate to Explosion, PATR No. 1658, 11 July 1947.

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(e) International Critical Tables, McGraw-Hill Book Co., N. Y., Land-Bornst.

G. D. Clift and B. T. Federoff, <u>A Manual for Explosives Laboratories</u>, Vol. II, Lefax Society, Inc., Philadelphia, 1943.

(f) R. J. Finkelstein and G. Gamow, <u>Theory of the Detonation Process</u>, NAVORD Report No. 90-46, 20 April 1947.

(g) George Feick, The Dissociation Pressure and Free Energy of Formation of Ammonium Nitrate, Arthur D. Little, Inc., J Am Chem Soc, 76, 5858-60 (1954).

(h) M. A. Cook and M. Taylor Abegg, Isothermal Decomposition of Explosives, University of Utah, <u>Ind Eng Chem</u>, June 1956, pp. 1090 to 1095.

³See footnote 1, page 10.

$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	(i) Also see the following Picatinny Arsenal	1 Technical Reports on Ammonium Nitrate:				
		$ \underline{5} \underline{6} \underline{7} \underline{8} \underline{9} $ $ \underline{695} 596 907 548 799 \\ \underline{145} 666 \underline{1117} 638 \underline{1369} \\ \underline{225} 676 \underline{1047} \underline{928} \underline{109} $				
	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$				

Ammonium Perchlorate

Composition:	Molecular Weight: (ClH_4NO_4)	117.5			
~ Cl 30.2	Oxygen Balance:				
N 12 0		+27.3			
N 11.9 NH _L ClO _L	Density: am/cc	1.95			
н 3.4	Molting Point: °C				
0 54.5	Meiring Point: C				
C/H Ratio	Freezing Point: °C				
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 67	Boiling Point: °C				
Sample Wt 20 mg Picatinny Arrenal Apparatus in 24	Refractive Index, n ^D ₂₀				
Sample Wt, mg 24	n ₂₅				
	n ₃₀				
Friction Pendulum Test:	Vacuum Stability Test:				
Steel Shoe Snaps	cc/40 Hrs, at				
Fiber Shoe Unaffected	- 100°C	0.10			
Rifle Bullet Impact Test: Trials	120°C	0.13			
%	120 C	0.20			
Explosions	135 C				
Partials	130 C	0.32			
Burned	200 Gram Bomb Sand Test:				
Unaffected	Sand, gm	6.0			
Explosion Temperature: °C	Sensitivity to Initiation:				
Seconds, 0.1 (no cap used)	Minimum Detonating Charge, gm				
1 5 435	Mercury Fulminate				
10	Lead Azide	0.20			
15	Tetryl	0.25			
20	Ballistic Martar, % TNT:				
	Trauzl Test, % TNT:				
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test:				
100% U	Condition				
We have hat 49 Hz	Confined				
70 Loss, 1st 40 mrs U.U2	Density, gm/cc				
70 Loss, 2nd 40 mrs 0.00 Evaluation in 100 Hz Normal	Brisance, % TNT				
Laplosion in 100 mis None	Detenation Pater				
Flammability Index:	 Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second 				
Hygroscopicity: %					
Volatility:					

Ammonium Perchlorate

Fragmentation Test:	Shaped Charge Effectiveness, $TNT = 100$:				
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones Steel Cones				
Density, gm/cc	Hole Volume				
Charge Wt, Ib	Hole Depth				
Total No. of Fragments:	Color: Colorless				
For TNT					
For Subject HE	Principal Uses: Explosive ingredient of				
3 inch HE, M42A1 Projectile, Lot KC-5:	as projectile filler				
Density, gm/cc					
Charge Wt, Ib					
Total No. of Fragments:	Method of Loading: Pressed or cast depending				
For TNT	on composition of mixture				
For Subject HE	Loading Density: gm/cc Variable				
Fragment Velocity: ft/sec At 9 ft At 251/6 ft	Storage:				
Density am/cc					
Denaity, giny ce	Method Dry				
Blast (Relative to TNT):	Hazard Class (Quantity-Distance) Class 9				
Air: Peak Pressure	Compatibility Group				
Impulse	Exudation None				
Energy					
	Solubility in Water				
Air, Confined:	gm/100 cc saturated solution:				
Impulse	0°C 12				
Under Water:	25 [°] C 20				
Peak Pressure	$60^{\circ}C$ 39				
Impulse					
Energy	Preparation:				
Underground: Peak Pressure	The perchlorates are prepared by the action of the acid on a suitable base; by the ther- mal decommosition of certain chlorates: and				
Impulse	by the electrolysis of chlorates (see origin).				
Energy	Heat of:				
	Formation, cal/gm 665				
Ammonium Perchlorate

Origin: (c)

E. Mitscherlich first prepared, in 1832, crystals of ammonium perchlorate from barium perchlorate and ammonium sulfate (Pogg Ann 25, 300). T. Schlosing treated a hot solution of sodium perchlorate with ammonium chloride, and on cooling, crystals of ammonium perchlorate were obtained (Comp rend, 73, 1269, [1871]). U. Alvisi treated a mixture of 76 parts of ammonium nitrate with 213 parts of sodium perchlorate, and obtained a crop of small crystals of ammonium perchlorate which were purified by recrystallization from hot water (German Patent, 103,993, 1898). A. Miolati mixed magnesium or calcium perchlorate with ammonium chloride and crystals of ammonium perchlorate deposited from the solution of very soluble magnesium or calcium chloride (German Patent, 112, 682, 1899).

References: 4

(a) W. R. Tomlinson, Jr., <u>Physical and Explosive Properties of Military Explosives</u>, PATR No. 1372, 29 November 1943.

(b) T. L. Davis, <u>The Chemistry of Powder and Explosives</u>, John Wiley and Sons, Inc., New York, 1943.

(c) J. W. Mellor, A Comprehensive Treatise on Inorganic and Theoretical Chemistry, Vol. II, Longmanns, Green and Co., London, 1922, p. 396.

(d) Also see the following Picatinny Arsenal Technical Reports on Ammonium Perchlorate:

<u>o</u>	<u>1</u>	<u>3</u>	<u>4</u>	5	6	2	
100	321	843 1783	354 604 854	1095 1725 2205	1726	1049 1969	
⁴ See footn	ote 1, pag	e 10.					

Composition:	Molecular Weight:	125
Barium nitrate 67	Oxygen Balance: CO ₂ % CO %	-3 +13
INT 33	Density: gm/cc Cast	2.55
	Melting Point: °C	
C/H Ratio	Freezing Point: °C	ang the completed
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	Martina Antonina
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 11 Sample Wt, mg 24	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	fermelista rollari Mesa rollari 70
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C	
Rifle Bullet Impact Test: Trials % Explosions		
Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm	26.8
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 385 10	Sensitivity to Initiation: Minimum Detonating Charge, g Mercury Fulminate Lead Azide Tetryl	m 0.20 0.10
20	Ballistic Mortar, % TNT:	Head and a second
	Trauzl Test, % TNT:	and a subscription of the subscription of
 75°C International Heat Test: % Loss in 48 Hrs 	Plate Dent Test: (a) Method	73/27 B
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Condition Confined Density, gm/cc Brisance, % TNT	Cast No 2.52 61
Flammability Index:	- Detonation Rate: Confinement	Anna Principa C
Hygroscopicity: % 30 [°] C, 90% RH 0.00	 Condition Charge Diameter, in. Density, gm/cc 	
Volatility:	Rate, meters/second	

Baratol

Booster Sensitivity Test:	Decomposition Equation:
Condition Cast	t Oxygen, atoms/sec
Tetryl, gm 100	(Z/sec)
Wax, in. for 50% Detonation 0.32	2 (ΔH, kcal/mol)
Wax, am	Temperature Range, °C
Density, gm/cc 2.5	5 Phase
Heat of:	Armor Plate Impact Test:
Combustion, cal/gm	
Explosion, cal/gm	60 mm Mortar Projectile:
Gas Volume, cc/gm	50% Inert, Velocity, ft/sec
Formation, cal/gm	Aluminum Fineness
Fusion, col/gm 75/25 Baratol 2.8	(d) 500-1b General Purpose Bombs:
Specific Heat: cal/am/°C (d) 75/25 Bara	tol
	Plate Thickness, inches
-75 0.152 75 0.280	e que su
0 0.147 85 0.213	11/1
25 0.180 90 0.201	
50 0.229 100 0.171	13/
Burning Rate:	174
cm/sec	Bomb Drop Test:
Thermal Conductivity: cal/sec/cm/°C	T7, 2000-Ib Semi-Armor-Piercing Bomb vs Concrete:
61-0-0-0-0-0-0-0-0-0-0-0-0-0-0-0-0-0-0-0	Max Safe Drop. ft
Coefficient of Expansion: Linear, %/°C	500-lb General Purpose Bomb vs Concrete:
Volume, %/°C	Height, ft
	Trials
Hardness, Mohs' Scale:	Unaffected
	Low Order
Young's Modulus: E', dynes/cm²	High Order
E, Ib/inch ²	1000-lb General Purpose Bomb vs Concrete:
Density, gm/cc	Barrenses
	Height, ft
Compressive Strength: Ib/inch ²	Trials
이 집안 이 이 집에 가지 않는 것이 없는 것이 없는 것이 없다.	Unaffected
Vapor Pressure:	Low Order
°C mm Mercury	High Order
	ngeneral and an and an
	The state of the s
	final states and

Fragmentation Test:	Shaped Charge Effectiveness, $TNT = 100$:		
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Cones Hole Volume Hole Depth		
Total No. of Fragments: For TNT	Color:		
For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib Total No. of Fragments: For TNT	Principal Uses: Bomb filler Method of Loading: Cast		
For Subject HE	Loading Density: am/cc 2.55		
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry		
Blast (Relative to TNT):	Hazard Class (Quantity-Distance) Class 9		
Air: Peak Pressure Impulse Energy	Compatibility Group Group I Exudation		
Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	<u>Preparation:</u> The appropriate weight of barium nitrate heated to about 90°C is added to molton TNT contained in a melting vessel equipped with an agitator. Continue mixing until uniform, and load by pouring at the lowest practical temperature. <u>Origin:</u> Baratol, an explosive containing barium nitrate and TNT, the proportions varied to suit the required purposes, was developed during World War I.		
	att men al manifest and		

Baratol

Sensitivity Tests	Performance	Tests, OSRD Rep	ort No. 5746	, 27 December	1945.
(c) Also see	the following	Picatinny Arsen	al Technical	. Reports on Ba	iratol:
	<u>o</u>	3	6	8	
	2010 2160	1783 2233	2226	2138	
(d) C. Lenchi	tz, W. Beach a	nd R. Valicky,	Enthalpy Cha	ng es, Heat of	Fusion and Specific
leat of Basic Exp.	Losives, PATR	No. 2504, Janua	ry 1959.		

Arium nitrate 50 Oxygen Balance: CO ₂ % -24 INT 35 CO % -7 Aluminum 15 Density: gm/cc 2.32 Melting Point: °C Melting Point: °C C/H Ratio Freezing Point: °C Impact Sensitivity, 2 Kg W: Boiling Point: °C Bureau of Mines Apparatus, cm 30 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 12 Pricatinny Arsenal Apparatus, in. 12 n ^D ₂₅ Sample Wt, mg 22 n ^D ₂₅ Friction Pendulum Test: Yacuum Stability Test: Steel Shoe cc/40 Hrs, at Fiber Shoe 100 °C Rifle Bullet Impact Test: Trials	
INT35CO %- 7Aluminum15Density: gm/cc2.32Melting Point: °CMelting Point: °CC/H RatioFreezing Point: °CImpact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm30 Sample Wt 20 mg Picatinny Arsenal Apparatus, in.12 	
Aluminum15Density: gm/cc2.32C/H RatioMelting Point: °CImpact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm30 Sample Wt 20 mg Picatinny Arsenal Apparatus, in.12 22Friction Pendulum Test: Steel Shoe Fiber Shoe22Kifle Bullet Impact Test: TrialsTrialsKifle Bullet Impact Test: TrialsTrials	
C/H Ratio Melting Point: °C Impact Sensitivity, 2 Kg Wt: Freezing Point: °C Bureau of Mines Apparatus, cm 30 Sample Wt 20 mg Boiling Point: °C Picatinny Arsenal Apparatus, in. 12 Sample Wt, mg 22 Friction Pendulum Test: n ^D / ₂₅ Steel Shoe cc/40 Hrs, at 90°C Fiber Shoe 100°C Rifle Bullet Impact Test: Trials	
C/H Ratio Freezing Point: °C Impact Sensitivity, 2 Kg Wt: Boiling Point: °C Bureau of Mines Apparatus, cm 30 Sample Wt 20 mg Refractive Index, n ^D ₂₀ Picatinny Arsenal Apparatus, in. 12 Sample Wt, mg 22 Friction Pendulum Test: N ^D ₂₅ Steel Shoe cc/40 Hrs, at Fiber Shoe 90°C Rifle Bullet Impact Test: Trials	
Impact Sensitivity, 2 Kg Wt: Boiling Point: °C Bureau of Mines Apparatus, cm 30 Sample Wt 20 mg Refractive Index, n ^D ₂₀ Picatinny Arsenal Apparatus, in. 12 Sample Wt, mg 22 Friction Pendulum Test: N ^D ₂₅ Steel Shoe cc/40 Hrs, at Fiber Shoe 90°C Rifle Bullet Impact Test: Trials	
Sample Wt 20 mg Refractive Index, ng Picatinny Arsenal Apparatus, in. 12 Sample Wt, mg 22 Friction Pendulum Test: Vacuum Stability Test: Steel Shoe cc/40 Hrs, at Fiber Shoe 90°C Rifle Bullet Impact Test: Trials	
Picatinny Arsenal Apparatus, in. 12 Sample Wt, mg 22 Friction Pendulum Test: n ^D ₂₅ Steel Shoe cc/40 Hrs, at Fiber Shoe 90°C Rifle Bullet Impact Test: Trials	
Steel Shoe CC/40 Hrs, at 90°C Rifle Bullet Impact Test: Trials	
Friction Pendulum Test: Vacuum Stability Test: Steel Shoe cc/40 Hrs, at Fiber Shoe 90°C Rifle Bullet Impact Test: Trials 100°C 120°C	
Steel Shoe cc/40 Hrs, at 90°C Rifle Bullet Impact Test: Trials 120°C	
Fiber Shoe 90°C Rifle Bullet Impact Test: Trials 120°C	
Rifle Bullet Impact Test: Trials	
%	
Explosions	
Partials 130°C	
Burned 200 Gram Bomb Sand Test:	
Unaffected Sand, gm 39.8	
Explosion Temperature: °C Sensitivity to Initiation:	
Seconds, 0.1 (no cap used) Minimum Detonating Charge, gm	
1 Mercury Fulminate	
Leod Azide 0.20	
Tetryl 0.10	
20 Ballistic Mortar, % TNT: (a) 96	
Trauzi Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs Method	
100°C Heat Tests	
% Loss 1st 48 Hzs Confined	
Density, gm/cc	
Explosion in 100 Hrs Brisance, % TNT	
Detonation Rate: (b)	
Flammability Index: Confinement None	
Condition Cast	
Hygroscopicity: % Charge Diameter, in. 1.0	
Density, gm/cc 2.32	
Rate, meters/second 5450	0.115

Baronal

Fragmentation Test:	Shaped Charge Effectiveness, $TNT = 100$:
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Cones Hole Volume Hole Depth
Total No. of Fragments: For TNT	Color:
For Subject HE	Principal Uses: Bomb filler
3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib	 Pranets Januarista, J. By Wh. Caster of Wrow, Sumain Science, Company, Comp Company, Company, Company,
Total No. of Fragments: For TNT	Method of Loading: Cast
For Subject HE	Loading Density: gm/cc 232
Fragment Velocity: ft/sec	Altha Rafar Roman Lines: Testi
At 9 ft At 25½ ft	Storage:
Density, gm/cc	Method Dry
Blast (Relative to TNT):	Hazard Class (Quantity-Distance) Class 9
Air: Peak Pressure Impulse	Compatibility Group Group I
Air, Confined:	Preparation:
Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Impulse	Procedure same as described under Baratol except aluminum is added to the barium ni- trate-TNT molton mixture under agitation until uniformity in comparison is obtained.Booster Sensitivity Test:(c)ConditionCast Tetryl, gmWax, in. for 50% Detonation0.86 Density, gm/ccDensity, gm/cc2.32
Energy	Heat of: Combustion, cal/gm 2099 Explosion, cal/gm 1135 Gas Volume, cc/gm 410

Baronal

References: 6

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.

M. D. Hurwitz, <u>The Rate of Detonation of Various Compounds and Mixtures</u>, OSRD Report No. 5611, 15 January 1946.

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) Arthur D. Little Report, Study of Pure Explosive Compounds, Part III, Correlation of Composition of Mixture with Performance, Contract No. DA-19-020-ORD-12, 1 May 1950.

(e) S. J. Lowell, Propagation of Detonation in Long and Narrow Columns of Explosives, PATR No. 2138, February 1955.

⁶See footnote 1, page 10.

Black Powder

Composition:	Molecular Weight:	84
% Potassium nitrate 74.0	Oxygen Balance: CO ₂ % CO %	-22 - 2
Sulfur 10.4	Density: gm/cc	Variable
Charcoal 15.6	Melting Point: °C	an more
C/H Ratio	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 16 Sample Wt, mg 16	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	
Friction Pendulum Test:	Vacuum Stability Test:	
Steel ShoeSnapsFiber ShoeUnaffected	cc/40 Hrs, at 90°C	0.5
Rifle Bullet Impact Test: Trials	120°C	0.9
%	135°C	
Explosions	150°C	
Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm	8
Explosion Temperature:°CSeconds, 0.1 (no cap used)51014905Ignites10356	Sensitivity to Initiation: Minimum Detonating Charge, Mercury Fulminate Lead Azide Tetryl Sensitive to igniting fus	gm
20	Ballistic Mortar, % TNT:	50
	Trauzi Test, % TNT: (a)	10
75°C International Heat Test:% Loss in 48 Hrs0.31	Plate Dent Test: Method	l Su
100°C Heat Test:	Condition	
% Loss, 1st 48 Hrs	Confined	
% Loss, 2nd 48 Hrs	Density, gm/cc	
Explosion in 100 Hrs	Brisance, % TNT	
Flammability Index:		
Hygroscopicity: 26°C, 75% RH 0.75 25°C, 90% RH 1.91 30°C, 90% RH 2.51	Condition Charge Diameter, in.	1.6
Volatility:	Rate, meters/second	400

Fragmentation Test:	Shaped Charge Effectiveness, TNT $=$ 100:
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Cones Hole Volume Hole Depth
Total No. of Fragments: For TNT	Color: Black
For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib	Principal Uses: 1. Igniter powder 2. Time rings (fuzes)
Total No. of Fragments: For TNT	Method of Loading: 1. Loose (granulated) 2. Pressed
For Subject HE Fragment Velocity: ft/sec At 9 ft At 25½ ft	Loading Density: gm/cc psi x 10 ³ 25 50 60 65 70 75 1.74 1.84 1.86 1.87 1.88 1.89 Storage:
Density, gm/cc	Method Dry
Blast (Relative to TNT):	Hazard Class (Quantity-Distance) Class 9
Air: Peak Pressure Impulse	Compatibility Group 0 Exudation None
Air, Confined: Impulse Under Water:	100°C Vacuum Stability Test,cc gas/40 hrs:Initial Value0.5After 2 hours at 65°C0.86After 2 hours at 65°C, 75% RH1.46
Peak Pressure Impulse Energy	Sensitivity to Electrostatic Discharge, Joules: (b)
Underground: Peak Pressure Impulse	Unconfined >12.5 Confined 0.8 Compatibility with Metals: Dry - Compatible with all metals when
Energy Initiating Efficiency:	Wet - Attacks all common metals except stainless steel.
Grams Required to Initiate	Heat of:
Igniter Comp K-312.0Igniter Comp K-292.3	Explosion, cal/gm 684 Gas Volume, cc/gm 271

Black Powder

Preparation:

Willow or alder charcoal, flour of sulphur and 2-3% of water are placed in a tumbling barrel and mixed for a short period (about 1/2 hour). The mixture is transferred to a "wheel mill" and crystalline potassium nitrate containing 3-4% moisture is added and the mixture is incorporated for several hours. During the incorporation period the mixture is kept damp (2-3% moisture) by adding water at intervals. The mill cake is then pressed at 6000 psi between aluminum plates. The pressed cakes are broken up between rubber or wood rolls. The material is screened and the various particle sizes are separated as desired. The screened material is then transferred to canvas trays and dried in hot air ovens at 60° C. If it is desired to glaze the black powder, the material before drying is polished by rotation in a tumbling barrel to give it a smooth surface. It is next screened to remove the dust. The smooth particles are then placed in a wooden barrel and rotated with graphite. The material is again screened to remove the excess graphite, and dried. Material finer than #40 U. S. Sieve is not graphited.

WARNING

The batches of black powder must be of sufficient size to cover the bed of the "wheel mill." If the wheels run off on the bare bed, explosions usually result.

Origin:

The exact date of the discovery of black powder is unknown. Historians attribute its discovery to the Chinese, Hindus or Arabs. The Greeks used it during the 7th Century. Marcus Graecus in the 9th Century and Roger Bacon in the 13th Century described compositions similar to the present powder. Beginning with the 16th Century, the composition of black powder containing potassium nitrate, charcoal and sulfur has remained unchanged with respect to the proportionality (75/15/10) of the ingredients.

Destruction by Chemical Decomposition:

Black powder can be desensitized by leaching with water to dissolve the potassium nitrate. The washings must be disposed of separately because the residue of sulfur and charcoal is combustible but not explosive.

References: 7

(a) Ph. Naoum, Nitroglycerine and Nitroglycerine Explosives, Baltimore, 1928.

(b) F. W. Brown, D. H. Kusler and F. C. Gibson, <u>Sensitivity of Explosives to Initiation by</u> Electrostatic Discharges, U. S. Department of the Interior, Bureau of Mines RI 3852, 1946.

(c) Also see the following Picatinny Arsenal Technical Reports on Black Powder:

See footnote 1, page 10.

Black Powder

$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	
2051 1602 1613 1154 1388 1739 1912 1843 1244 1528 1869 1973 1504 1778 1889 1838 1928 2178	
and a second sec	

Composition:		Molecular Weight: $(C_4H_7N_30_9)$	241
$\begin{array}{c} & 19.9 \\ H & 2.9 \\ H & 2.9 \end{array} \begin{array}{c} H_2 C - 0 N O_2 \\ H_2 C \end{array}$		Oxygen Balance: CO ₂ % CO %	-17 10
N 17.5		Density: gm/cc Liquid	1.52
0 59.7 HC-0N02		Melting Point: °C	Press All
C/H Ratio 0.13		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	58	Boiling Point: °C	
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	≦l	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	1.4738
Friction Pendulum Test: Steel Shoe Fiber Shoe		Vacuum Stability Test: cc/40 Hrs, at 90°C	
Rifle Bullet Impact Test: Trials		100°C 120°C	2.33
% Explosions Partials		135°C 150°C	
Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm	48.6
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decormoses 230		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate	
10		Lead Azide Tetryl	0.20
20		Ballistic Mortar, % TNT:	
		Trauzl Test, % TNT:	
 75°C International Heat Test: % Loss in 48 Hrs 		Plate Dent Test: Method	
100°C Heat Test:		Condition	
% Loss, 1st 48 Hrs	1.5	Contined	
% Loss, 2nd 48 Hrs	1.2	Brisonce % TNIT	
Explosion in 100 Hrs	None		
Flammability Index:		Detonation Rate: Confinement	
Hygroscopicity: % (a) 100 ⁰ F, 95% RH, 24 hrs	0.14	Condition Charge Diameter, in. Density am/cc	
Volatility: 60°C, mg/cm ² /hr	46	Rate, meters/second	

1,2,4-Butanetriol Trinitrate (BTIN) Liquid

AMCP 706-177

Fragmentation Test:		Shaped Charge Effectiveness, TNT = 100:		
90 mm HE, M71 Projectile, Lot WC- Density, gm/cc Charge Wt, Ib	91:	Glass Cones St Hole Volume Hole Depth	ee! Cones	
Total No. of Fragments:		Color: Yellow	oil	
For INI		ANTESTRO MARCHAR OF LA CERTA A	an include the first of	
For Subject HE	-5:	Principal Uses: Explosive pl nitrocellulo	asticizer for se	
Density am/cc				
Charge Wt Ib		and the mail applied and by King		
Charge Htty in		ne lêfter seland normalisations militar	and an arrest state	
Total No. of Fragments: For TNT		Method of Loading:		
Fragment Velocity: ft/sec			B granza	
At 251/2 ft		Storage:		
Density, gm/cc		Method		
Blast (Relative to TNT):	And the second second	Hazard Class (Quantity-Distanc	e)	
Air: Peak Pressure		Compatibility Group		
Impulse		Exudation		
Energy				
Air, Confined:		Solubility in Water, gm/100 gm, at:	(a)	
mpuse		20 ⁰ C	0.08	
Under Water:		60°C	0.15	
Peak Pressure		Solubility of Water in,	(a)	
Impulse		<u>gm/100 gm:</u>	0.04	
Energy		Solubility, gm/100 gm, at 25°C, in:		
Underground: Peak Pressure		Ether Alcohol	00 00	
Impulse		2:1 Ether:Alcohol	~	
Energy		Acetone		
Heat of:	(a)	Viscosity, centipoises:	(a)	
Combustion, cal/gm Explosion, cal/gm Gas Volume, cc/gm	2168 1457 840	Temp, 25°C	59	

Preparation (Laboratory Procedure):

To a cooled mixture of 73.8 gm of 100% nitric acid, 46.2 gms of 106.2% sulfuric acid and 60.0 gm of 96.1% sulfuric acid, 30 gms of the original (or redistilled) 1,2,4-butanetriol was added dropwise with agitation for a period of thirty minutes. The temperature of the reaction mixture was kept at $0^{\circ}-5^{\circ}$ C. When the agitation was completed, stirring was continued for one and one-half hours. The mixture was poured into ice water, and the resulting oil suspension was extracted with three 100 milliliter portions of ether. The combined ether extracts were washed with water, then with a 5% sodium bicarbonate solution and finally with water. The neutralized extract was dried with anhydrous calcium chloride and then the ether was evaporated. The yellow oil was dried in a vacuum desiccator over anhydrous calcium chloride until the material was brought to constant weight.

Origin:

1,2,4-butanetriol was first synthesized by Wagner and Ginsberg in 1894 by oxidizing allyl carbinol with potassium permanganate under mild conditions (Ber <u>27</u>, 2437). Recently the U. S. Rubber Laboratory, under the direction of P. Tawney, devised a new synthesis carried out with allyl acetate and formaldehyde to give 1,2,4-butane triacetate which was readily hydrolysed to butanetriol (U. S. Rubber Company Quarterly Report, May 1948). Working with pure 1,2,4-butanetriol prepared by an improved technique of the Wagner method, the U. S. Naval Laboratory in 1948 nitrated the butanetriol on a laboratory and a pilot plant scale (Reference a).

References: 8

(a) J. A. Gallaghan, F. Macri, J. Bednarik, and F. McCollum, <u>The Synthesis of 1,2,4-Butane-</u> triol and the Evaluation of Its Trinitrate, U. S. Naval Powder Factory Technical Report No. 19, 10 September 1948.

(b) Also see the following Picatinny Arsenal Technical Reports on Butanetriol Trinitrate: 1755 and 1786.

⁸See footnote 1, page 10.

Composition:	the poor Chillings III	Molecular Weight:		227
% RDX 91		Oxygen Balance: CO ₂ %	a alternative C	-48
Wax 9		Density: gm/cc 12,	000 psi	1.65
		Melting Point: °C		
C/H Ratio		Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt:	100+	Boiling Point: °C	Street A	
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	16 17	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀		
Friction Pendulum Test:	and the second second second	Vacuum Stability Test:		
Steel Shoe Unaff Fiber Shoe Unaff	ected ected	cc/40 Hrs, at 90°C 100°C		0.3
Rifle Bullet Impact Test: Trials % % Explosions 0		120°C 135°C 150°C		0.6
Burned 0 Unaffected 100		200 Gram Bomb Sand T Sand, gm	est:	51.5
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 25 10	0	Sensitivity to Initiation: Minimum Detonating Mercury Fulminate Lead Azide) Charge, gm e	0.22* 0.25*
15		Ballistic Mortar. % TN	$\mathbf{T}: (a)$	1 25
20	ando er tige - At tor a dat date Antoine	Trauzi Test, % TNT:	·· (a)	
75°C International Heat Test: % Loss in 48 Hrs	n nand an an Parati an wa Parati an ar	Plate Dent Test: Method	(b) B	В
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs	0.15 0.15 None	Condition Confined Density, gm/cc Brisance, % TNT	Pressed No 1.61 126	Pressed No 1.20 75
Flammability Index:	195	Detonation Rate: Confinement	(c)	None
Hygroscopicity: % 30°C, 90% RH	0.0	Condition Charge Diameter, in		Pressed 1.0
Volatility: 50°C, 15 days	0.03	Density, gm/cc Rate, meters/second		1.59 8100

Fragmentation Test:		Shaped Charge Effectiveness, $TNT = 100$:				
90 mm HE, M71 Projectile, Lo	t WC-91:	Glass Cones Steel Cones				
Density, gm/cc	1.62	Hole Volume				
Charge Wt, Ib	2.102	Hole Depth				
- 1903 - 18 ANA						
Total No. of Fragments:		Colory				
For TNT	703	White-buff				
For Subject HE	1138		and program			
3 inch HF. M42A1 Projectile 1	of KC-5	Principal Uses: HE, SAP, AP project Shaped Charges	tiles;			
Density am/cc	1.64	- Kh No Autoreque Countries				
Change Mit Ib	0.867					
Charge Wt, Ib	0.001					
Total No. of Fragments:						
For TNT	514	Method of Loading: Pressed				
For Subject HF	710	THEFT PLANAUL				
		Loading Density: am/cc psi x 10	₀ 3			
	5 68	3 12	and and the second second second			
Fragment Velocity: ft/sec	2800	1.47 1.65	Solid States			
At $25\frac{1}{2}$ ft	2530	Storage:				
Density, am/cc	1.61					
		Method Dry				
	he of firmt ments little					
Blast (Relative to TNT):		Hazard Class (Quantity-Distance) Clas	ss 9			
Air:		Compatibility Group Grou	ıp I			
Peak Pressure		has a spin of 2 of				
Impulse		Exudation Does not exude at 65°C	when waxe			
Energy		melting sharply at or above 75°C	are used.			
		Preparation:				
Air, Confined:		A water slurry of RDY is hested t	0.100 ⁰ C			
Impulse		with agitation. Wax and a wetting	agent are			
AT THE AND A CONTRACT OF		added and the mixture, under agitat	tion, is			
Under Water: Peok Pressure		cooled below the melting point of t	the wax.			
Impulse		and air dried at 75°C.	a iiitter			
Eperov		Effect of Temperature on				
chergy		Rate of Detonation:	(e)			
Underground:		16 brs at. °C -54	21			
Peak Pressure		Density, gm/cc 1.51	1.51			
Impulse		Rate, m/sec 7600	7620			
Energy		Booster Sensitivity Test:	(d)			
(electron)		Condition	Pressed			
		Tetryl, gm	100			
		Wax, in. for 50% Detonation	1.70			
		Density, gm/cc	1.62			
		Heat of:				
		Combustion, cal/gm	1210			

Compatibility with Metals:

Dry - Aluminum, stainless steel, mild steel, mild steel coated with acid-proof black paint and mild steel plated with nickel or zinc are unaffected. Copper, magnesium, magnesium-aluminum alloy, brass and mild steel plated with cadmium or copper are slightly affected.

Wet - Stainless steel is unaffected. Copper, aluminum, magnesium, brass, mild steel, mild steel coated with acid-proof black paint and mild steel plated with copper, cadmium, nickel or zinc are slightly affected.

Origin:

Developed by the British during World War II as RDX and beeswax. Subsequent changes in the United States replaced beeswax with synthetic waxes, changed the granulation of RDX and improved the method of manufacture.

Destruction by Chemical Decomposition:

RDX Composition A-3 (RDX/wax, 91/9) is decomposed by adding it slowly to 25 times its weight of boiling 5% sodium hydroxide. Boiling of the solution is continued for one-half hour.

References: 9

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(c) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.

M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.

(d) L. C. Smith and S. R. Walton, <u>A Consideration of RDX/Wax Mixtures as a Substitute for</u> Tetryl in Boosters, NOL Memo 10,303, dated 15 June 1949.

(e) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November 1956.

(f) Also see the following Picatinny Arsenal Technical Reports on RDX Composition A-3:

0	<u>1</u>	2	3	<u>14</u>	5	<u>6</u>	<u>7</u>	<u>8</u>	2
1380 1910	1451 1761	1492 2112	1493	1424 1614 1634 2154	1325 1585 1595 1715 1885 2235	1556 1936	1687 1787 1797	1338 1388 1728 1838	1639 2179

Composition:		Molecular Weight:		224	a same	
RDX 60		Oxygen Balance; CO ₂ % CO %	i edinika a tenden denteden	-43 10		
INT 40		Density: gm/cc Ca	ast	1.65	- Hay	
Wax, added 1		Melting Point: °C	(1)	78-80		
C/H Ratio		Freezing Point: °C			en Esperat	
Impact Sensitivity, 2 Kg Wt:	75	Boiling Point: °C	nt ili pel	r vi todyr	evot.	
Bureau of Mines Apparatus, cm 75 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 14 Sample Wt, mg 19		Refractive Index, n ^D ₂₀ n ^D ₂₅ n ³⁰				
Friction Pendulum Test:Steel ShoeUnaffectedFiber ShoeUnaffected		Vacuum Stability Test: cc/40 Hrs, at 90°C	ing a start of a start		nol sa Intint	
Rifle Bullet Impact Test: Trials	1 202 30 2014	100°C		0.7		
. %		120°C		0.9		
Explosions 3		150°C		11+		
Partials 13			In Printing			
Unaffected 80		Sand, gm		54.0		
Explosion Temperature:°CSeconds, 0.1 (no cap used)52613685Decomposes27810255	in poor team of an	Sensitivity to Initiation: Minimum Detonating Cha Mercury Fulminate Lead Azide Tetryl	urge, gm	0.22* 0.20*		
15 > 250		* Alternative initiati	ing charg	ges		
20 > 2 50		Ballistic Mortar, % TNT:	(a)	133	181	
75°C International Heat Test:		Trauzi Test, % TNT:	(b)	130		
% Loss in 48 Hrs		Plate Dent Test: Method	(c)	в		
100°C Heat Test:		Condition		Cast		
% Loss, 1st 48 Hrs	0.2	Confined		No		
% Loss, 2nd 48 Hrs	0.2	Brisonce % TNIT		1.55		
Explosion in 100 Hrs	None			175		
Flammability Index:	177	Detonation Rate: Confinement		None		
Hygroscopicity: % 30°C, 90% RH	0.02	Charge Diameter in		Cast		
		Density, gm/cc		1.68		
V.I. ette				2141		

Booster Sensitivity Test:	(d) Cast	Decomposition Equation	:		
Condition	100	(Z/sec)			
Tetryl, gm	100	Heat, kilocalorie/mol	e		
Wax, in. for 50% Detonation	1.40	(ΔH, kcal/mol)			
Wax, gm	and the second second	Temperature Range,	°C		
Density, gm/cc	1.69	Phase			
Heat of:	(e) 2700	Armor Plate Impact Tes	t:	(e)	
Combustion, cal/gm	2190				
Explosion, cal/gm	1240	60 mm Mortar Projec	tile:	000	
Gas Volume, cc/gm		50% Inert, Velocit	ry, ft/sec	209	
Formation, cal/gm		Aluminum Finenes	s		
Fusion, cal/gm (1)	8.0	500-1b General Purpo	se Bombs:		
Secultic Heat collar (°C (1)	And the second second				
on on on		Plate Thickness, in	iches		
<u> </u>			Trials	% Inert	
-75 0.235 75	0.376	1	4	100	
0 0.220 85	0.354	11/4	6	50	
25 0.254 90 50 0.305 100	0.312]1/2	2	0	
JC 0. 50 100		134	0		
Burning Rate:					
	the should be	Bomb Drop Test:			
Thermal Conductivity: cal/sec/cm/°C		T7, 2000-lb Semi-Art	mor-Piercing B	lomb vs Con	crete:
	and other of the second	Max Safe Drop, ft			
Linear, %/°C		500-lb General Purp	ose Bomb vs (Concrete:	
Volume % /°C			NO Seat	hooo	
volume, 707 C		Height, ft	4000	4000	
Handmann Make' Saalar		Trials	65	39	
maraness, mons Scale:		Unaffected	58	36	
Yaunata Maduluri	a mailing an addition	Low Order	2	2	
Toung's Modulus:		High Order	5	1	
E', dynes/cm ²					
E, lb/inch ²		1000-Ib General Purj	oose Bomb vs (Concrete:	
Density, gm/cc					
		Height, ft			
Compressive Strength: Ib/inch ² (1	b) 1610-2580	Trials			
Density, gm/cc	1.00	Unaffected			
		Low Order			
Vapor Pressure:		· · · · · · · · · · · · · · · · · · ·			
Vapor Pressure: °C mm Mercu	ry	High Order			

Fragmentation Test:	Stateshipun-slave Filmatin Dolygen, arrenter dr	Shaped Charge Effectiveness, $TNT = 100$:
90 mm HE, M71 Projectile, Lot	WC-91:	(g) (h) Glass Cones Steel Cones
Density, gm/cc	1.65	Hole Volume 178 162
Charge Wt, Ib	2.187	Hole Depth 125 148
Total No. of Fragments:		
For TNT	703	Color: Yellow-brown
For Subject HE	998	
3 inch HF M4241 Projectile Le	+ KC.5.	Principal Uses: Fragmentation bombs, HE projectiles, grenades, shaped
Density om/cc	1.67	charges
Charge Wt. Ib	0.882	and the market market
charge with b		and the second
Total No. of Fragments:		Mathed of Londings
For TNT	514	Method of Lodding: Cast
For Subject HE	701	is a start of the
		Loading Density: gm/cc 1.68
Fragment Velocity: ft/sec		
At 9 ft	2940	
At 25½ ft	2680	Storage:
Density, gm/cc	T.00	Method
	TOP & DESIGNAR APPRICAL	
Blast (Relative to TNT):	(f)	Hazard Class (Quantity-Distance) Class 9
Air:		Compatibility Group Group I
Peak Pressure	110	Constitution of Lagoretica,
Impulse	110	Exudation Very slight when stored at 71°C
Energy	116	i i i i i i i i i i i i i i i i i i i
		Origin:
Air, Confined:	75	DDV. Comparition Dama and approximate
	to a bit with t	British between World War I and World War IT.
Under Water:	magg gappet 1	It was standardized by the United States
Peak Pressure	110	early in World War II.
Impulse	108	Effect of Temperature on
Energy	121	Rate of Detonation: (i)
Underground:		16 hrs at, °C -54 24
Peak Pressure	104	Density, gm/cc 1.69 1.69 Rate, m/sec 7720 7660
Impulse	97	Pulls Medulus at Deem
Energy		Temperature (25°-30°C):
Crater radius cubed	107	" Way in Comp P 3 0
		$Dynes/cm^2 \times 10^{-10}$ 5.10 3.56 2.34
		Density, gm/cc 1.72 1.70 1.68
		Viscosity, poises:
and a second sec	n anna an an Anna Anna Anna Anna Anna A	95°C 3.1

Compatibility with Metals:

Dry - Magnesium, aluminum, magnesium-aluminum alloy, mild steel, stainless steel, mild steel coated with acid-proof black paint and mild steel plated with zinc or nickel are unaffected. Copper, brass and mild steel plated with copper or cadmium are slightly affected.

Wet - Aluminum and stainless steel are unaffected. Copper, brass, mild steel, mild steel coated with acid-proof black paint and mild steel plated with cadmium, copper, nickel or zinc are slightly affected. Magnesium and magnesium-aluminum alloy are more heavily affected.

Preparation:

Water wet RDX is added slowly with stirring to molten TNT melted in a steam-jacketed kettle at a temperature of 100°C. Some water is poured off and heating and stirring are continued until all moisture is evaporated. Wax is then added and when thoroughly mixed, the composition is cooled to a satisfactory pouring temperature. It is cast directly into ammunition components or in the form of chips when Composition B is to be stored.

Destruction by Chemical Decomposition:

RDX Composition B is decomposed in 12 parts by weight of technical grade acetone heated to 45°C. While this is stirred vigorously, there is added 12 parts of a solution, heated to 70°C, of 1 part sodium sulfide (Na₂S'9H₂O) in 4 parts water. The sulfide solution is added slowly so that the temperature of the acetone solution does not rise above 60°C. After addition is complete, stirring is continued for one-half hour.

References: 10

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) Philip C. Keenan and Dorothy Pipes, <u>Table of Military High Explosives</u>, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) L. C. Smith and S. R. Walton, <u>A Consideration of RDX/Wax Mixtures as a Substitute for</u> Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(e) Committee of Divisions 2 and 8, NDRC, <u>Report on HBX and Tritonal</u>, OSRD Report No. 5406, 31 July 1945.

(f) W. R. Tomlinson, Jr., <u>Blast Effects of Bomb Explosives</u>, PA Tech Div Lecture, 9 April 1948.

(g) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W672-ORD-5723.

(h) Eastern Laboratory du Pont, <u>Investigation of Cavity Effect</u>, Final Report, E Lab du Pont, Contract W-672-ORD-5723, 18 September 1943.

(i) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November, 1956.

¹⁰See footnote 1, page 10.

(j) W. S. Cramer, Bulk Compressibility Data on Several High Explosives, NAVORD Report No. 4380, 15 September 1956.

(k)	Also see th	he follow	ing Picat:	inny Arse	nal Techn	ical Repo	rts on RD	X Composi	tion B:
<u>o</u>	<u>1</u>	2	<u>3</u>	<u>4</u>	5	<u>6</u>	<u>7</u>	<u>8</u>	2
1360 1530 2100 2160 2190	1211 1451 2131 2151	1402 1482 1592	1313 1433 1803 1983 2053 2063 2103 2233	1224 1424 1944 2004 2104	1325 1435 1585 1595 1865 1885 2055 2125 2155 2155 2175 2235	1466 1476 1556 1756 1956 2236	1207 1437 1457 1737 1797 2007 2147	1338 1388 1438 1458 1688 1728 1828 1828 1838 1978 2008 2138 2168	1339 1379 1469 1819 2019

(1) C. Lenchitz, W. Beach and R. Valicky, Enthalpy Changes, Heat of Fusion and Specific Heat of Basic Explosives, PATR No. 2504, January 1959.

Composition B, Desensitized

AMCP 706-177

a transferration and the service of a second			F	T¥	TT¥¥
Composition:	<u>I*</u>	<u>II**</u>	Molecular Weight: See Cy	<u>rclonite</u>	See Comp B
70 RDX	60	55.2	Oxygen Balance:		
TNT Wax, added. (Stanolind	40	40.0	CO ₂ % See C ₃	clonite	See Comp B
or Aristowax, 1650/	5		CO % See Cj	clonite	See Comp B
Vinylseal (MA28-14),	2		Density: gm/cc Cast	1.65	1.65
Vistanex (Bl20) Albacer Wax		1.2 3.6	Melting Point: °C	Weight Ba	
C/H Ratio	-		Freezing Point: °C	jus e au	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	<u>1*</u> 95	<u>II**</u>	Boiling Point: °C		n Ritabath
Sample Wt 20 mg	-1		Refractive Index, n ^D ₂₀		
Picatinny Arsenal Apparatus, in.	14	13	N25		
Sample W(, mg	±1	10	n ₃₀		
Friction Pendulum Test:		in sections.	Vacuum Stability Test		TT**
Steel Shoe Unaffed	eted		cc/40 Hrs. at	<u> </u>	
Fiber Shoe Unaffed	eted		90°C		
			- 100°C		
Rifle Bullet Impact Test: Irials	T¥	TT¥¥	120°C	0.99	0.92
% Explosions	<u>1*</u>	<u>11**</u>	135°C		
Partials	0	0	150°C	11+	11+
Burned	5	0	200 Gram Bomb Sand Test:	T¥	TT XX
Unoffected	95	100	Sand, am	52.7	55.0
	T X	TTXX	· ··· · · · · · · · · · · · · · · · ·		77 -
Explosion Temperature: °C	<u>T*</u>	TT**	Sensitivity to Initiation:	<u>1</u> *	TT
Seconds, 0.1 (no cap used)			Marcuny Eulminate	, giii	
5 Decomposes	260	270	Lood Azida	0.22	0.26
10			Tetry	0.22	0.20
15					
20			Ballistic Mortar, % TNT:		- 05 1. 19 1. - 05 1. 19 1.
TISC Internet Hant Test			Trauzi Test, % TNT:		
% Loss in 48 Hrs			Plate Dent Test: Method		
100°C Heat Test:	I*	II **	Condition		
% Loss, 1st 48 Hrs	0.05	0.12	Confined		
% Loss, 2nd 48 Hrs	0.19	0.18	Density, gm/cc		
Explosion in 100 Hrs	None	None	Brisance, % TNT		
			Detonation Rate:		
Flammability Index:			Confinement		
Hyaroscopicity: %			Change Dispersion		
30°C, 90% RH	0.00	0.00	Charge Diameter, in.		
Volatility:	Nil	Nil	Density, gm/cc		
			Kate, meters/second		

*Desensitized Comp B, designated I, uses emulsified wax. **Desensitized Comp B, designated II, uses coated RDX.

	and the state of the				
Fragmentation Test:		Shaped Charge	Effectivene	ss, TNT $=$ 100	Campiantian :
90 mm HE, M71 Projectile, I	ot WC-91:	9.5	Glass Con	es Steel Co	nes
Density am/cc		Hole Volum	e		Cash Init (special
Charge Wt. Ib		Hole Depth			duhu kaka wa na
					to is triple in
Total No. of Fragments:		Color:		Yellow-h	രണ
For TNT		Color.		101100-01	
For Subject HE					
		Principal Uses:		Bombs	distant summer
3 inch HE, M42A1 Projectile,	Lot KC-5:	- The second sec			Marine Constraints
Density, gm/cc	1.65 1.65				the weather of
Charge Wt, Ib	0.87 0.86				Contractor Anna
Total bla of Fragments					
Total No. or Pragments:	51), 51),	Method of Loa	iding:	Cast	where the second states and
	600 650				
For Subject HE	009 009	Loading Densit	w. am/cc	1 65	the second second
	54001	Louding Dentil	y, gill/ cc	1.0)	and the second s
Fragment Velocity: ft/sec			ne in	Sup Tap Tap	e phanet and a second
At 25½ ft		Storage:			
Density, gm/cc		- 0			
rede de selfense anderes services en proprieter en anna en anna en a		Method		Di	су
	and here and hand the	Hazard Clas	s (Quantity-	Distance) C	lass 9
Blast (Kelative to INI):					
Air:		Compatibilit	ty Group	G	roup I
Peak Pressure		1			
Impulse		Exudation			
Energy		- 1 P	12114	The second s	
		Viscosity,	poises:	I *	II**
Air, Confined:		 000)a		2.1
Impulse		1 Temp, 03	°C °C	3.2	3.1
Under Water:			and the second second		induced in the second
Peak Pressure		References:	_		
Impulse		(a) See	the follo	wing Picati	nnv Arsenal
Energy		Technical F	Reports on	RDX Compos:	ition B,
He deserve de		Desensitize	ed:		 M. Long, Lt.
Peak Pressure		1	3	5	6
Impulse				alies	
Energy		5121	2053	1865	1120
			_0/5	1007	
*Desensitized Comp B, des	signated I, uses	Second Seco			
emulsified wax.	Compact of application	20.5			
**Desensitized Comp B, des	signatea 11, uses	March Area Area Area Area Area Area Area Area			
COULCUTION.					

Composition:	Molecular Weight:
RDX 88.3 Plasticizer, non-	Oxygen Balance: CO.º % CO %
explosive 11.7*	Density: gm/cc
*Nonexplosive oily plasticizer containing 0.6% lecithin.	Melting Point: °C
C/H Ratio	Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 100+	Boiling Point: °C
Sample Wt 20 mg Picatinny Arsenal Apparatus in	Refractive Index, n ^D ₂₀
Sample Wt, mg	n ^D 25
Friction Pendulum Test:	Vacuum Stability Test:
Fiber Shoe	cc/40 Hrs, at 90°C
	- 100°C 0.3
Kifle Builet Impact Test: I rials	120°C 0.7
Frolosions 0	135°C
Portials	150°C
Burned 0	200 Grow Bowk Sand Task
Unaffected 100	Sand, gm 46.5
Explosion Temperature: °C	Sensitivity to Initiation:
Seconds, 0.1 (no cap used)	Minimum Detonating Charge, gm
Bulgation . Jantas eterne to V	Mercury Fulminate
5 Decomposes 285	Lead Azide 0.25
10	Tetryl 0.11
20	Ballistic Mortar, % TNT: (a) 120
	Trauzl Test, % TNT:
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test:
	Method A
100°C Heat Test:	Condition Hand Tamped
% Loss, 1st 48 Hrs 0.04	Confined Yes
% Loss, 2nd 48 Hrs 0.00	Density, gm/cc 1.58
Explosion in 100 Hrs None	Brisance, % TNT 112
Flammability Index:	Detonation Rate:
Hygroscopicity: % 30°C, 95% RH 0.25	Condition Charge Diameter, in.
Volatility: 25°C, 5 days 0.00	Density, gm/cc Rate, meters/second

Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100: (f) (g)
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones Steel Cones
Density, gm/cc	Hole Volume 113 114
Charge Wt, Ib	Hole Depth 101 114
Total No. of Fragments: For TNT	Color: White
For Subject HE	Principal Uses: Plastic demolition explosive
3 inch HE, M42A1 Projectile, Lot KC-5:	Bankar Bushiliting The West
Density, gm/cc	in the state of the second sec
Charge Wt, Ib	 President and an advance of the second se Second second sec
Total No. of Fragments:	Method of Loading: Hand tamped
For TNT	COLORA AND AND AND AND AND AND AND AND AND AN
For Subject HE	Loading Density: gm/cc 1.49
E	- Andrew Control of the Article of the second se
At 9 ft At 251/2 ft	Storage:
Density, gm/cc	Method Dry
Blast (Relative to TNT):	Hazard Class (Quantity-Distance) Class 9
Alter all aller and a second	Compatibility Group Group I
Peak Pressure	
Impulse	Exudation Exudes above 40°C
Energy	
	Plasticity:
Air, Confined:	
Impulse	Below 0°C Brittle (0°C)
Under Water:	Above 40°C Exudes (40°C)
Peak Pressure	Defense of the state of the sta
Impulse	References:
Energy	See references for Composition C-4.
Underground:	
Peak Pressure	an and a second and a
Impulse	- NAMES STATES AND
Energy	Tanan Market Taking State
	Primaration is still - i at a second
	the second s

Composition:		Molecular Weight:	
% RDX 78.7 INT 5.0 DNT 12.0		Oxygen Balance: CO ₂ % CO %	n 1496, 201 Marcha Antonio glas 201 Alternationentico - 1
MNT 2.7 NC 0.6		Density: gm/cc	and the second large of
Solvent 1.0		Melting Point: °C	an a
C/H Ratio		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:	90	Boiling Point: °C	CALLARY ON DOALS
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	hen i ta badana	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe Fiber Shoe	ran and parts and parts	cc/40 Hrs, at 90°C	
Rifle Bullet Impact Test: Trials		120°C	2.0
%		135°C	3.0
Explosions 0		150°C	
Partials 20			
Burned 0 Unaffected 80		200 Gram Bomb Sand Test: Sand, gm	47.5
Explosion Temperature: °C Seconds, 0.1 (no cap used)		Sensitivity to Initiation: Minimum Detonating Charge, gn Mercury Fulminate	n terest terest Includes
5 Decomposes 285		Lead Azide	0.25
10		Tetryl	0.10
15 20		Ballistic Mortar, % TNT: (a)	126
	and a little of the little of the same of	Trauzi Test, % TNT:	a manager and and
75°C International Heat Test: % Loss in 48 Hrs		Plate Dent Test: (c) Method	B
100°C Heat Test:		Condition H	and tamped
% Loss, 1st 48 Hrs	1.8	Confined	No
% Loss, 2nd 48 Hrs	1.4	Density, gm/cc	1.52
Explosion in 100 Hrs	None	Brisance, % TNT	111
Flammability Index:	178	- Detonation Rate: (d) Confinement	None
Hygroscopicity: % 30°C, 95% RH	0.55	 Condition Charge Diameter, in. 	Hand tamped 1.0
Volatility: 25°C, 5 days	0.00	 Density, gm/cc Rate, meters/second 	1.57 7660

Fragmentation Test:	A state of the second sec	Shaped Charge Effectiven	less, TNT = 100:
90 mm HE, M71 Projectile Density, gm/cc	e, Lot WC-91:	Glass Co Hole Volume	nes Steel Cones
Charge Wt, Ib		Hole Depth	
Total No. of Fragments: For TNT		Color:	White
For Subject HE		Principal Uses: Plast:	ic demolition explosive
3 inch HE, M42A1 Projecti Density, gm/cc	ile, Lot KC-5:	internet (1991) al 14 milionato e decemento e meso. CO teo d	
Charge Wt, Ib		ell ,	(a provide state of states at a
Total No. of Fragments: For TNT		Method of Loading:	Hand tamped
For Subject HE	Proposes to Statistic Parts decisi II al	Loading Density: gm/cc	1.57
Fragment Velocity: ft/sec At 9 ft At 25½ ft		Storage:	ante protectiones Réferències fragmen l'august l'a
Density, gm/cc		Method	Dry
Blast (Relative to TNT):	2003 Street Court Provide 1007 Street, Col-	Hazard Class (Quantit	y-Distance) Class 9 Group I
Peak Pressure		Eucletian Volat	ilizes showe 520C
Impulse Energy			
Air, Confined: Impulse		Plasticity: Below 0 ⁰ C	Plastic (-30°C)
Under Water: Peak Pressure		0-40°C above 40°C	Plastic Hard (52 ⁰ C)*
Impulse		*Due to volitalizat	tion of plasticizer.
Energy		References:	
Underground: Peak Pressure		See references fo	or Composition C-4.
Impulse		11 - 12 111 St 1	
Energy		participant of the same secondary through	
		. Opt	
		and a second	
		ល្មប៉ុន្តថំ ។ ស្រុកប្រ	with the W

Composition:		Molecular Weight:	Fragmenter Street			
% RDX Tetryl INT	77 3 4	Oxygen Balance: CO ₂ % CO %	115, 31, we be wine games			
DNT MNT	10 5	Density: gm/cc				
NC	1 0000	Melting Point: °C	i amainn an th			
C/H Ratio		Freezing Point: °C				
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	100+	Boiling Point: °C	45964 ,814 Aug (\$			
Sample Wt 20 mg	٦.),	Refractive Index, n ^D ₂₀				
Sample Wt, mg	33	n ₂₅ ^D				
L SECTOR DECIMA	Andra I. the departments	n ₃₀	Tatel etc. as fictor			
Friction Pendulum Test:		Vacuum Stability Test:				
Steel Shoe Unaff	ected	cc/40 Hrs, at				
Fiber Shoe Unaff	ected	90°C	1 01			
Rifle Bullet Impact Test: Trials		100°C	1.21			
. %		120°C	11+			
Explosions 0		135°C	Danates, emeral			
Partials 40		150°C				
Burned 0		200 Gram Bomb Sand Test:				
Unaffected 60		Sand, gm	53.1			
Explosion Temperature: °C	Anterio de C	Sensitivity to Initiation:	nia nicitatri dent			
Seconds, 0.1 (no cup used)		Marcuny Fulminate	Service Harris			
5 Decomposes 280			0.20			
10		Totad	0.08			
15			0.00			
20		Ballistic Mortar, % TNT: (a)	126			
		Trauzi Test, % TNT: (b)	117			
% Loss in 48 Hrs		Plate Dent Test: (c)				
		Method	В			
100°C Heat Test:		Condition Hand	l tamped			
% Loss, 1st 48 Hrs	3.20	Confined	No			
% Loss, 2nd 48 Hrs	1.63	Density, gm/cc	1.57			
Explosion in 100 Hrs	None	Brisance, % TNT	118			
		Detonation Rate: (d)	A DOWNER OF			
Flammability Index:		Confinement	None			
Hydroscopicity: % 30°C 05% PH	2.4	Condition Hand	tamped			
	L	Charge Diameter, in.	1.0			
Volatility: 25°C, 5 davs	1.15	Density, gm/cc	1.60			
		Rate, meters/second	7625			

Fragmentation Test:	Health Antonian	Shaped Charge Effectiv	reness, TNT $=$ 100:	
90 mm HE, M71 Projectile, Lot WC-5	Glass Cones Steel Cones			
Density, gm/cc	158	Hole Volume		
Charge Wt, Ib	2045	Hole Depth		
		D.		224
Total No. of Fragments:		Color:	Yellow	2.17
For TNT	703		10110.	
For Subject HE	944	Principal Uses: Pla	astic demolition	explosive
3 inch HE, M42A1 Projectile, Lot KC-	5: model palled			
Density, gm/cc	1.60	1		
Charge Wt. Ib	0.842			
				N. Hillingia
Total No. of Fragments:		Method of Loading:	Hand tamp	ed
For TNT	514			
For Subject HE	671			
The second		Loading Density: gm/c	c 1.5	8
E Valacity ft/soc	Pat Section 2			
At 9 ft			AND SHEET THEY	REAL DURING STREET
At 251/2 ft		Storage:		
Density, gm/cc				Destr
		Method		Dry
	r	Hazard Class (Quar	ntity-Distance)	Class 9
Blast (Kelative to INI):			i i	
Air		Compatibility Group	0	Group I
Peak Pressure	105			
Impulse	109	Exudation	Exudes at 77°C	
Energy				1
		Plasticity.		
Air, Confined:		1100010100.		61
Impulse		Below O ^O C	Hard	(-29°C)
and the second state of th		0-40°C	Plas	$(77^{\circ}c)$
Under Water:		Above 40°C	Exua	5 (11 0)
Feak Fressure		Booster Sensitivi	ty Test: (h)	
Impulse			Deeg	- A
Energy		Condition	Pres.)
Underground		Wax, in. for 50	% Detonation 1.	36
Peak Pressure		Density, gm/cc	1.0	62
Impulse		Poferences		
Energy		Aererences:		
		See references	for Composition	c-4.
i de la companya de l				
		1		

Composition:	Molecular Weight:			
% RDX 91	Oxygen Balance: CO ₂ %			
Plasticizer, non- explosive 9*				
* Contains polyisobutylene 2.1%; motor oil	Density: gm/cc			
1.0% and di(2-ethylnexyl) sebacate 5.3%.	Melting Point: °C			
C/H Ratio	Freezing Point: °C			
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 100+	Boiling Point: °C			
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 19 Sample Wt, mg 27	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀			
Friction Pendulum Test:	Vacuum Stability Test:			
Steel Shoe Unaffected	cc/40 Hrs, at			
Fiber Shoe Unaffected	90°C			
Rifle Bullet Impact Test: Trials	120°C			
Suplasiana 0	135°C			
Partials 0	150°C			
Burned 20	200 Gram Bomb Sand Test:			
Unaffected 80	Sand, gm 55.7 and tool			
Explosion Temperature: °C Seconds, 0.1 (no cap used)	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate			
5 290	Lead Azide 0.20			
10	Tetryl 0.10			
15	Ballistic Mortar, % TNT: (a) 130			
	Trauzi Test, % TNT:			
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: (c) Method B			
100°C Heat Test:	Condition Hand tamped			
% Loss, 1st 48 Hrs 0.13	Confined No			
% Loss, 2nd 48 Hrs 0.00	Density, gm/cc 1.60			
Explosion in 100 Hrs None	Brisance, % TNT 115			
Flammability Index:	Detonation Rate: (d) Confinement None			
Hygroscopicity: % 30°C, 95% RH Nil	Condition Hand tamped Charge Diameter, in. 1.0			
	Density, gm/cc 1.59			
Yolatility:	Rate, meters/second 8040			

Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100:
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc	Glass Cones Steel Cones Hole Volume
Charge Wt, Ib	Hole Depth
Total No. of Fragments: For TNT	Color: Light brown
For Subject HE	Principal Uses: Plastic demolition explosive
3 inch HE, M42A1 Projectile, Lot KC-5:	Angert Committing, 3 rig was
Density, gm/cc	Sample Writers
Charge Wt, Ib	Prostrikowy Arton († Konsten), sie 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 19
Total No. of Fragments:	Method of Looding: Hand tamped
For TNT	Relation Productions Frain
For Subject TE	Loading Density: gm/cc 1.60
Fragment Velocity: ft/sec	in the second
At 9 ft At 251/ ₂ ft	Storage:
Density, gm/cc	Method Dry
Blast (Relative to TNT):	- Hazard Class (Quantity-Distance) Class 9
Air: Duottetuos or agaideme?	Compatibility Group Group I
Peak Pressure	Nove of 7770
Impulse	Exudation None at (C
Energy	
	Effect of Temperature on (i)
Air, Confined: Impulse	Rate of Detonation:
	16 hrs at, °C -54 21
Under Water:	Density, gm/cc 1.36 1.35
Peak Pressure	Rate, m/sec (020 (040
Impulse Energy	Plasticity:
S7	Below 0° C Diretia (-57°C)
Underground: Peak Pressure	$\begin{array}{ccc} \text{Below O'C} & \text{Plastic} & (77^{\circ}\text{C}) \\ \text{O-40}^{\circ}\text{C} & \text{Plastic} & (77^{\circ}\text{C}) \\ \text{Above 40}^{\circ}\text{C} & \text{Plastic} & (77^{\circ}\text{C}) \\ \end{array}$
Impulse	2 Profession
Energy	Planetality takes
	management and a second s
	1.10 No. 1 No. 1 March 100
	A statistical second se Second second secon second second sec
	142011 GMP X

Preparation:

In manufacturing Composition C-3, the mixed plasticizing agent is heated in a melting kettle at 100°C. Water-wet RDX is added and heating and stirring are continued until all the water is evaporated. This mixture is then cooled and hand pressed into demolition blocks or special item ammunition.

Composition C-4 is prepared by hand kneading and rolling, or in a Schrader Bowl mixer, RDX of 44 micron size or less with the polyisobutylene-plasticizer previously made up in ether. The thoroughly blended explosive is dried in air at 60° C and loosely packed by hand tamping to its maximum density.

Origin:

Developed by the British during World War II as a plastic explosive which could be hand shaped. It was standardized in the United States during World War II and subsequent development led to mixtures designated C-2, C-3 and C-4.

Destruction by Chemical Decomposition:

Composition C-3 is decomposed by adding it slowly to a solution composed of 1 1/4 parts sodium hydroxide, 11 parts water, and 4 parts 95% alcohol, heated to 50° C. After addition of Composition C-3 is complete, the solution is heated to 80° C and maintained at this temperature for 15 minutes.

References: 11

(a) Committee of Div 2 and 8, NDRC, Report on HBX and Tritonal, OSRD No. 5406, 31 July 1945.

(b) Philip C. Keenan and Dorothy Pipes, <u>Table of Military High Explosives</u>, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

L. C. Smith and E. G. Eyster, <u>Physical Testing of Explosives</u>, Part III - <u>Miscellaneous</u> Sensitivity Tests; Performance Tests, <u>OSRD Report No. 5746</u>, 27 December 1945.

(d) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.

M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.

(e) W. R. Tomlinson, Jr., <u>Blast Effects of Bomb Explosives</u>, PA Tech Div Lecture, 9 April 1948.

(f) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W672-ORD-5723.

(g) Eastern Laboratory, du Pont, <u>Investigation of Cavity Effect</u>, Final Report, 18 September 1943, NDRC Contract W-672-ORD-5723.

(h) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

¹¹See footnote 1, page 10.

Compositions C, C-2, C-3, C-4

(i) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Temperatures, PATR No. 2383, November 1956.

(j) Also see the following Picatinny Arsenal Technical Reports on RDX Composition C:

	<u>o</u>	1	3	<u>1</u>	5	6	7	8	2
Comp C	1260		1293					1518 1838	
Comp C-2 Comp C-3		1611	1293 1713	2154	1595 1695 1885	1416 1416 1556 1766	1797	1518 1518 2028	
Comp C-4					100)	1766	1907	1828 1958	1819

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Copper Chlorotetrazole

Composition:	Molecular Weight: (CuC ₂ N ₈ Cl ₂) 271	in regime 1
$\begin{array}{c} 70 \\ C \\ N \\ N \\ 41.5 \end{array} N \\ N \\$	Oxygen Balance: CO % -30 CO % -18	4.09 ett.
Cl 26.2 N - N	Density: gm/cc 2.04	
Cu 23.4	Melting Point: °C	
C/H Ratio	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus cm	Boiling Point: °Ć	nt of T
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 1; (1 1b wt) 3 Sample Wt, mg 9	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	
Friction Pendulum Test:Steel ShoeExplodedFiber ShoeExploded	Vacuum Stability Test: cc/40 Hrs, at 90°C	
Rifle Bullet Impact Test: Trials % Explosions Partials	- 100°C 120°C 135°C 150°C	
Burned Unaffected	200 Gram Bomb Sand Test: (f) Sand, gm 27.4 25.3 Black powder fuse 17.0	et page a
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 305 10 15	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 0.30 Tetryl 0.10	
20	Ballistic Mortar, % TNT:	di la composición de la composicinde la composición de la composición de la composic
	Trauzl Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method	
100°C Heat Test: % Loss, 1st 48 Hrs 2.67 % Loss, 2nd 48 Hrs 0.10 Explosion in 100 Hrs None	Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:	- Detonation Rate: Confinement	
Hygroscopicity: % 30°C, 90% RH 3.11	Condition Charge Diameter, in.	
Volatility:	Density, gm/cc Rate, meters/second	
Copper Chlorotetrazole

Fragmentation Test:	Shaped Charge Effectiveness, TNT $=$ 100:
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc	Glass Cones Steel Cones Hole Volume
Charge Wt, Ib	Hole Depth
Total No. of Fragments: For TNT	Color: Blue
For Subject HE	Principal Uses: Primary explosive
3 inch HE, M42A1 Projectile, Lot KC-5:	Beging Standards, S. Ku, Will. Depart Standards, S. Ku, Mill.
Density, gm/cc	Shinow WI 20 mg
Charge Wt, Ib	 S. Constrained and the statement of the stat
Total No. of Fragments:	Method of Loading: Pressed
For TNT	Friction Fondulem Fatti
For Subject HE	Loading Density: gm/cc psi x 10 ³ (c)
Fragment Velocity: ft/sec	10 20 40 70 1.49 1.63 1.74 1.86
At 9 ft At 25½ ft	Storage:
Density, gm/cc	Method Wet also and
Blast (Relative to TNT):	Hazard Class (Quantity-Distance) Class 9
Air:	Compatibility Group Group M
Peak Pressure	Exudation None
Energy	
Litergy	Stab Consitivity:
Air, Confined: Impulse	Density Firing Point (inch-ounces)
Transl Care, 15 1141	gm/cc 0% 50% 100%
Under Water:	1.49 9 11 15
Impulse	1.63 8.5 10 12
Energy	1.74 6 7 9 1.86 4 5 6
Condiana (International International Intern	
Underground: Peak Pressure	Heat of:
Impulse	Explosion, cal/gm
Energy	Specific Heat, cal/gm/ ^O C
Cheviliteus Chèrge Dimosgan, m	Temp range 0°-30°C 0.155 Wt of sample, gm 0.8910
Distriction persident Statements environments	Solution in the second s
Manufacture and a state of the	l have been been been been been been been be

Copper Chlorotetrazole

Preparation: (a)

Five grams of 5-aminotetrazole are dissolved in a mixture of 200 ml of water and 70 ml of concentrated HCl. Enough kerosene or nujol (which gives a slightly cleaner product) is added to provide a layer of oil approximately 1/4" thick on the surface. With only moderate stirring and external cooling to $10^{\circ}-15^{\circ}$ C, a solution of 5 grams of sodium nitrite in 70 cc of water is added rapidly by means of a burette extending below the oil layer. Immediately after this addition, a solution of 5 gms of cupric chloride in a minimum amount of water is added all at once, and stirring is continued for about 1 hour. The reaction mixture is allowed to stand for a few minutes till the bright blue copper salt separates. The oil is removed by decantation and may be reused. The salt is filtered; washed with water, alcohol, and ether; and dried - giving a yield of 6 grams or 74%.





Origin:

The copper salt of 5-chlorotetrazole was first described in 1929 by R. Stolle (with E. Schick, F. Henke-Stark and L. Krauss) who prepared the compound by reaction of the diazonium chloride of 5-aminotetrazole with copper chloride (Ber 62A, 1123).

References: 12

(a) R. J. Gaughran and J. V. R. Kaufman, <u>Synthesis and Properties of Halotetrazole Salts</u>, PATR No. 2136, February 1955.

(b) A. M. Anzalone, J. E. Abel and A. C. Forsyth, <u>Characteristics of Explosive Substances</u> for Application in Ammunition, PATR No. 2179, May 1955.

(c) A. C. Forsyth, Pfc, S. Krasner and R. J. Gaughran, <u>Development of Optimum Explosive</u> <u>Trains. An Investigation Concerning Stab Sensitivity versus Loading Density of Some Initiating</u> <u>Compounds</u>, PATR No. 2146, February 1955.

¹²See footnote 1, page 10.

Cyanuric Triazide

Composition:	Molecular Weight: (C ₃ N ₁₂)	204
$^{\%}$ C 17.6 N_3	Oxygen Balance: CO ₂ % CO%	-47.1 -23.5
N 02.4	Density: gm/cc Crystal	1.54
	Melting Point: °C	94
C/H Ratio	Freezing Point: °C	A PL CONTRACT OF
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	
Bureau of Mines Apparatus, cm 1 kg wt 7 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C	1
Rifle Bullet Impact Test: Trials	100°C 120°C	
% Explosions	135°C 150°C	
Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm	32.2
Explosion Temperature: °C Seconds, 0.1 (no cap used) 252 1 5	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide	0.20
10 15		0.10
20		C
75°C International Heat Test: % Loss in 48 Hrs 100°C Heat Test:	Plate Dent Test: Method Condition	n (n fr) Statut (n) Statut (n fr)
% Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Density, gm/cc Brisance, % TNT	
Flammability Index:	Confinement	-
Hygroscopicity: %	Charge Diameter, in.	0.3 1.15
Volatility: Decomposes above 100°C	Rate, meters/second	550-5600

Fragmentation Test:	Shaped Charge Effectiveness, T	NT = 100:
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Hole Volume Hole Depth	Steel Cones
Total No. of Fragments: For TNT	Color:	Colorless
For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib	Principal Uses: Not used be in controll	ecause of difficulty Ling sensitivity.
Total No. of Fragments: For TNT For Subject HE	Method of Loading:	Pressed
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Loading Density: gm/cc At 200 atmospheres At 800 atmospheres Storage: Method	1.4 1.5
Blast (Relative to TNT):	Hazard Class (Quantity-Dista	nce) Class 9
Air: Peak Pressure	Compatibility Group	
Impulse Energy	Exudation	None
Air, Confined: Impulse		
Under Water: Peak Pressure		
Impulse Energy		
Underground: Peak Pressure	nie terzy, and Galler. Harbertot, Annes an Nigel, VI	
Impulse Energy	n <u>da</u> maranakan sementikan	
	a design of the second second	

Cyanuric Triazide

Preparation:

By the reaction of cyanuric chloride with an aqueous solution of sodium azide:



Recrystallization should be avoided as it leads to very large crystals which explode when broken.

Origin:

Cyanuric Triazide was prepared in 1847 by Cahours from chlorine and methyl cyanate. Later James improved the process (JCS <u>51</u>, 268 (1887) and in 1921 E. Ott patented the preparation from cyanuric chloride and sodium azide (Ref b) Taylor and Rinkenbach prepared cyanuric triazide in a pure state and determined its properties (Ref c).

Initiating Efficiency:

Reported to be more efficient than lead azide. Capable of initiating Explosive D.

Solubility:

Insoluble in water; readily soluble in hot ethanol, acetone, benzene, and ether.

Heat of:

Formation, cal/gm -1090 to -1138

References: 13

(a) A. H. Blatt, Compilation of Data on Organic Explosives, OSRD Report No. 2014, 29 February 1944.

- (b) Ott and Ohse, Ber 54, 179 (1921).
- (c) Taylor and Rinkenbach, Bureau of Mines, RI 2513 (1923).

Taylor and Rinkenbach, J Frank Inst 204, 369 (1927).

¹³See footnote 1, page 10.

an di selaman na panganan kara tana ing kara na			
Composition:		Molecular Weight: $(C_3H_6N_6O_6)$) 222
C 16.3 02N-N N-	-NO2	Oxygen Balance;	and her of the
	Restrict Hall	CO %	-22 0.0
	2		
N 37.8 N		Density: gm/cc Crystal	1.82
0 43.2 NO ₂		Melting Point: °C	204
C/H Ratio 0.095		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	32	Boiling Point: °C	na andar and
Sample Wt 20 mg	8	Refractive Index, n ^D ₂₀	
Sample Wt, mg	18	n ₂₅	
		n ₃₀	
Friction Pendulum Test:	PINELS I RAUTE	Vacuum Stability Test:	
Steel Shoe Explo	des	cc/40 Hrs, at	
Fiber Shoe Unaff	ected	90°C	
Rifle Bullet Impact Test: Trials		- 100°C	0.7
		120°C	0.9
Explosions 100		135°C	fanal peirs a
Partials 0		150°C	2.5
Burned 0		200 Gram Bomb Sand Test:	
Unaffected 0		Sand, gm	60.2
Explosion Temperature: °C	its short your	Sensitivity to Initiation:	
Seconds, 0.1 (no cap used) 405		Minimum Detonating Charge, g	m
1 316		Mercury Fulminate	0.19*
5 Decomposes 200		Lead Azide	0.05*
10 240		Tetryl * Alternative initiating cha	-
15 235		Ballistic Mortar, % TNT: (a)	150
20	Line Deler	Trauzi Test, % TNT: (b)	157
75°C International Heat Test:	nilah-Ordain	Plate Dent Test: (c)	Propies and
% Loss in 48 Hrs	0.03	Method	A
100°C Heat Test		Condition	Pressed
% Loss. 1st 48 Hrs	0.04	Confined	Yes
% Loss, 2nd 48 Hrs	0.00	Density, gm/cc	1.50
Explosion in 100 Hrs	None	Brisance, % TNT	135
	ביין באמיין	Detonation Rate:	A Transfer Linear V
Flammability Index: (d)	278	Confinement	None
		- Condition	Pressed
Hygroscopicity: % 25°C, 100% RH	0.02	Charge Diameter, in.	1.0
Valatilituu	NT# 7	- Density, gm/cc	1.65
volatility:	INTT	Rate, meters/second	8180

*Name given by Clarence J. Bain of Picatinny Arsenal. Germans call it Hexogen; Italians call it T4; British, RDX.

Cyclonite (RDX)

Booster Sensitivity Test: Condition	Decomposition Equation: (i) Oxygen, atoms/sec 10 ^{18.5}
Tetryl om	(Z/sec)
Were in for 50% Deterrotion	Heat, kilocalorie/mole 47.5
wax, in. for 50% Detonation	(ΔH, kcal/mol) Temperature Pange °C 213-209
Wax, gm	Temperature Kunge, C 215-299
Density, gm/cc	Phose Liquid
Heat of: Combustion, cal/am 2285	Armor Plate Impact Test:
Explosion chl/am 1280	
Cos Valumo as (am	60 mm Mortar Projectile:
Gds volume, cc/gm	Al asises Figures
Formation, cal/gm =90	Aluminum Fineness
Solution, cal/mol (20-55% HNO3) (.109"	500 lb Canaval Rumasa Rombs:
Assuming cyclonice unimolecular	SOU-ID General Purpose bombs.
Specific Heat: cal/gm/°C	Plate Thickness, inches
	a concernante anticamba
20 0.290 100 0.400	112 Tak Look (
60 0.360 140 0.446	174
80 0.384	1 1/2
	- 134
Burning Rate:	a standard a
cm/sec	Bomb Drop Test:
	The second se
cal/sec/cm/°C $1.263 6.91 \times 10^{-4}$	T7, 2000-Ib Semi-Armor-Piercing Bomb vs Concrete:
	Max Safe Drop, ft
Linear, %/°C	500-1b General Purpose Bomb vs Concrete:
Volume %/°C	Height ft
lyis)	
Hardness, Mohs' Scale: 2.5	
Young's Modulus:	Low Order
E' dynes/cm ²	High Order
E lb/inch ²	1000 Ib Concerd Ruspace Romb ve Concertor
Density am/cc	TUUU-ID General Furpose bomb 45 Concrete:
Density, gitty co	Height ft
Comprosing Strongth: Ib/inch2	Triols
compressive strength; ib/ inch-	
°C mm Mercury	Low Order High Order
	The second se
	and the second sec
chelle and a second	

Fragmentation Test:	Shaped Charge Effectiveness, TNT $=$ 100:
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Cones Hole Volume Hole Depth
Total No. of Fragments: For TNT	Color: White
For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib	Principal Uses: Detonator base charge, and ingredient for projectile and bomb fillers
Total No. of Fragments: For TNT	Method of Loading: Pressed
For Subject HE Fragment Velocity: ft/sec	Loading Density: gm/cc psi x 10 ³ 3 5 10 12 15 20
At 9 ft At 25½ ft	Storage:
Blast (Relative to TNT): Air: Peak Pressure Impulse	MethodWetHazard Class (Quantity-Distance)Class 9Compatibility GroupGroup M (wet) Group L (dry)ExudationNone
Air, Confined: Impulse	Effect of Temperature on Rate of Detonation: (k)
Under Water: Peak Preșsure	10 nrs at, -C -54 21 Density, gm/cc 1.61 1.62 Rate, m/sec 8100 8050
Impulse Energy	Effect of Temperature on Impact Sensitivity:
Underground: Peak Pressure Impulse Energy	Temp. OCPA Impact Test 2Kg Wt, inchesRoom9
y)	32.2 8 104 5

Cyclonite (RDX)

Water	Alcohol	Acetone	Benzene	Toluene	
oc g 30 0.005 50 0.025 70 0.076 90 0.19 100 0.28	o % 0 0.040 20 0.105 40 0.240 60 0.579 78 1.195	$ \frac{\circ_{\rm C}}{\circ} \frac{9}{4.4} 20 7.3 40 11.5 60 18. $	° <u>c</u> <u>%</u> 20 0.05 40 0.09 60 0.20 80 0.41	$\begin{array}{c c} \circ c & \frac{1}{2} \\ \hline 0 & 0.015 \\ 20 & 0.02 \\ 40 & 0.05 \\ 60 & 0.13 \\ 80 & 0.30 \\ 100 & 0.65 \end{array}$	
Ethyl acetate	Carbon tetrachloride	Methanol	Ether	TNT	
° <u>c</u> <u>%</u> 28 2.9 94 18.	<u>°с </u> <u>¢</u> 50 0.005 60 0.007 70 0.009	$ \frac{\circ_{C}}{\circ} \frac{\cancel{6}}{0.14} 20 0.23 40 0.47 60 1.1 $	<u>°</u> <u>°</u> 10 0.05 20 0.056 30 0.076	$\begin{array}{c} \circ_{\rm C} & g_{\rm c} \\ \hline 80 & 4.4 \\ 85 & 5.0 \\ 90 & 5.55 \\ 95 & 6.2 \\ 100 & 7.0 \\ 105 & 7.9 \end{array}$	
Isoamyl alcohol	Methyl acetate	<u><i>B</i>-Ethoxyethyl</u> acetate	Chlorobenzene	Trichloro- ethylene	
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	oc # 20 2.9 30 3.3 40 4.1 50 5.6	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	°C % 20 0.33 30 0.44 40 0.56 50 0.74	$ \begin{array}{c} $	
<u>Tetra-</u> chloroethane	<u>Isopro-</u> panol	Isobutanol	Chloroform	Mesityloxide	
<u>°c %</u> 38 0.09	<u>°c </u> <u>%</u> 38 0.18	<u>°c </u>	<u>°c 4</u> 20 0.01	<u>°C</u> <u>%</u> 27 <u>3.2</u> 97 12.2	
Cyclo- hexanone	Nitro- benzene	Nitro- ethane	<u>Cyclo-</u> pentanone	Acetonitrile	
<u>°c</u> <u>%</u> 25 12.7 97 25	<u>°C</u> <u>%</u> 25 1.5 97 12.4	<u>°c ∦</u> 28 3.6 93 19	<u>°C</u> <u>%</u> 28 11.5 90 37	<u>°C</u> <u>%</u> 28 11 82 33	
	Methy	l ethyl ketone			
	<u>ос</u> 28 95				

(:)

Solubility of Cyclonite, Holston Lot E-2-5 in Various Solvents:

			<u>50.</u> gi	n/100 gm Solvent	
Solvent	Boiling Point, OC	Grade or Source*	<u>28°c</u>	Heated	Crystalline Form
Acetone	56	CP	8.2	16.5 at 60°C	hexagonal-thick
Cyclohexanone	155.6	CP	13.0	24.0 at 93°C	cubic (massive form)
Nitromethane	100.8		1.5	12.4 at 97°C	plates
Acetonitrile	81.6	Miacet Chem. Co.	11.3	33.4 at 93°C	plates
1-Nitropropane	126.5	EK Pract	1.4	10.6 at 93°C	short needles
2-Nitropropane	120	EK Pract	2.3	11.6 at 93°C	short needles
2,4-Pentanedione	140.5	Carbide & Carbon	2.9	18.3 at 93°C	flat prisms
Methylisobutylketone	115.8		2.4	9.6 at 93°C	long prisms
n-Propylacetate	101.6	EK Red Label	1.5	6.0 at 93°C	long prisms, some cubic
n-Butylformate	105.6	EK Red Label	1.4	4.6 at 930C	long prisms
Ethyl acetate	77.1	Baker's CP	2.0	6.1 at boil.	hexagonal plates
n-Propylpropionate	121	EK Red Label	0.8	1.6 at 93°C	short prisms, some cubic
Butylacetate	126.5	EK Technical	1.1	4.0 at 93°C	long prisms
Methylethylketone	79.6		5.6	13.9 at boil.	coarse plates
Nitroethane	114.2	EK Red Label	3.6	19.5 at 93°C	plates
Isopropylacetate	88-90	CP	1.1	3.2 at boil.	long prisms
Mesityloxide	128	EK Red Label	4.8	14.5 at 93°C	plates
n-Amylacetate	146	CP	1.0	2.1 at 93°C	prisms
Dimethylcarbonate	88-91	EK Red Label	1.4	6.6 at boil.	plates
Diethylcarbonate	125-126.5	EK Red Label	0.7	3.2 at 930C	prisms
Isoamylacetate	132	CP	1.2	3.6 at 93°C	prisms
Ethylpropionate	98-100	EK Red Label	3.0	10.7 at 93°C	fairly thick hex
Notherl a butamoto	101 E 102 E	THE Ded Tebel	1.0	1 0 at 0000	plates
Gualemontenana	101.7-103.5	EN Red Label	1.2	4.9 at 93°C	neeales
A amul and trid a	130.0	Chronomid C-	11.7	39.0 at 93.5°C	nexagonal plates
Acry Lonitrile	11.3	Cyanamia Co.	4.0	10.4 at boil.	Tlat plates
Me unit certosorveacera.	Le 144.5	Carbide &	1.0	0.0 at 93°C	massive hexagons and prisms

* EK, Eastman Kodak; Pract, practical.

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Cyclonite (RDX)

Preparation:

(Summary Technical Report of the NDRC, Div 8, Vol 1)



(CH₂)₆ N₄ + 4HNO₃ + 2NH₄NO₃ + 6(CH₃CO)₂ O

Ammonium nitrate and acetic anhydride are placed in a flask and, while the mixture is stirred at 75°C, the following three liquids are introduced concurrently and proportionately: acetic anhydride, concentrated nitric acid, and a solution of hexamine in glacial acetic acid. The final mixture is held for a short time at 75°C, diluted with water to 30% acetic acid, and simmered to hydrolyze unstable reaction by-products, which are a mixture of various nitrated and acetylated derivatives of hexamine fragments. After simmering, the slurry is cooled and the precipitated cyclonite removed by filtration. The yield is 78% of the theoretical amount (2 moles) of cyclonite melting at 199°C. By dissolving the ammonium nitrate in the nitric acid, a continuous process, based on 3 liquids, is possible.

The product is recrystallized from acetone, or cyclohexanone, to (a) remove acidity, (b) control particle size and (c) to produce stable β -HMX. The preparative procedure described above, the Bachmann or Combination process, yields cyclonite containing 3-8% HMX.

Origin:

First prepared by Henning in 1899 (German Patent 104,280) and later by von Hertz (U. S. Patent 1, 402,693) in 1922 who recognized its value as an explosive. Not used on a large scale in explosive ammunition until World War II.

Destruction by Chemical Decomposition:

Cyclonite (RDX) is decomposed by adding it slowly to 25 times its weight of boiling 5% sodium hydroxide. Boiling should be continued for one-half hour.

References: 14

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) Ph. Naoum, Z. ges Schiess Sprengstoffw, pp. 181, 229, 267 (27 June 1932).

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) Philip C. Keenan and Dorothy Pipes, <u>Table of Military High Explosives</u>, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

¹⁴See footnote 1, page 10.

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Cyclonite (RDX)

(e) Armament Research Department (Woolwich), Solubility of RDX in Nitric Acid (ARD Expl Rpt 322/43 September 1943).

(f) Report AC-2587.

(g) <u>International Critical Tables</u> Land. Bornst.

B. T. Fedoroff et al, <u>A Manual for Explosives Laboratories</u>, Lefax Society Inc, Philadelphia, 1943-6.

(h) E. Hutchinson, The Thermal Sensitiveness of Explosives. The Thermal Conductivity of Explosive Materials, AC 2861, First Report, August 1942.

(i) R. J. Finkelstein and G. Gamow, <u>Theory of the Detonation Process</u>, NAVORD Report No. 90-46, 20 April 1947.

(j) International Critical Tables.

(k) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November 1956.

(1) Also see the following Picatinny Arsenal Technical Reports on Cyclonite:

<u>0</u>	<u>1</u>	2	<u>3</u>	<u>14</u> .	5	6	<u>7</u>	8	2
1170 1290 1360 1450 1760 1980 2100	1211 1241 1311 1421 1481 1561 1651 1741 1751 1761 2131 2151	582 1342 1352 1372 1402 1452 1492 1532 2062 2112	863 1193 1293 1433 1483 1503 1693 1713 1793 1923	1184 1414 1454 1614 1634 2024 2154 2204	65 1175 1435 1445 1715 1855 1885 1915 1935 2095 2125 2205	1236 1316 1446 1466 1476 1516 1756 1756 1766 1766 1936 1936 2016 2016 2056	857 1207 1427 1517 1517 1617 1617 1687 1737 1747 1787 1797 1957 2147 2227	1438 1458 1498 1578 1838 1958 2008 2028 2178 2198	709 1379 1429 1449 1469 1709 1909 2059 2179

Composition:	Molecular Weight: 224				
RDX 75	Oxygen Balance: -35 CO ₂ % -35 CO % -6				
INT 25	Density: gm/cc Cast 1.71				
	Melting Point: °C				
C/H Ratio	Freezing Point: °C				
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C				
Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀				
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C				
Rifle Bullet Impact Test: Trials	- 100°C 0.23 120°C 0.41				
% Explosions 30 Particle Smokes 40	135°C - 150°C -				
Burned 0 Unaffected 30	200 Gram Bomb Sand Test: Sand, gm				
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10 15	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl Ballistic Mortar, % TNT:				
20	Trauzi Test. % TNT:				
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method				
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Evolosion in 100 Hrs	Condition Confined Density, gm/cc Brisance, % TNT				
Flammability Index:	- Detonation Rate: Confinement None None				
Hygroscopicity: %	Condition Cast Cast Charge Diameter, in. 1.0 1.0				
Volatility:	Density, gm/cc 1.70 1.71 Rate, meters/second 8035 7938				

Cyclotol, 75/25

AMCP 706-177

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH, kcal/mol) Temperature Range, °C Phase
Heat of:	Armor Plate Impact Test:
Combustion, cal/gm 2023*	a minimum services and a state state of a service of
Explosion, cal/gm	60 mm Mortar Projectile:
Gas Volume, cc/gm 002	50% Inert, Velocity, ft/sec
Formation, cal/gm	Aluminum Fineness
Calculated from composition of mixture.	500-lb General Purpose Bombs:
Specific Heat: cal/am/°C (h)	Tetal No. of Emerality
°c °c	Plate Thickness, inches
	a and the later with
-75 0.220 75 0.352	1
25 0.254 90 0.332	
50 0.296 100 0.351	1 172
Burning Rate:	Demots provide
	Bomb Drop Test:
Thermal Conductivity: cal/sec/cm/°C	T7, 2000-Ib Semi-Armor-Piercing Bomb vs Concrete:
	— Max Safe Drop, ft
Linear, %/°C	500-lb General Purpose Bomb vs Concrete:
Volume, %/°C	Height, ft
	- Trials
Hardness, Mohs' Scale:	Unaffected
	Low Order
Young's Modulus:	High Order
E, aynes/cm [*]	
E, ID/Inch"	1000-Ib General Purpose Bomb vs Concrete:
Density, gm/ cc	Height ft
Compressive Strength: Ib/inch ²	Trials
	Unoffected
	low Order
°C mm Mercury	High Order
and the second se	

Cyclotol, 75/25

Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100:
90 mm HE, M71 Projectile, Lot WC-91:Density, gm/cc1.72Charge Wt, Ib2.22	Glass Cones Steel Cones Hole Volume Hole Depth
Total No. of Fragments:	Color:
For TNT 703	Yellow-buir
For Subject HE 1514	Disistillar Chanad shange homb samesially
3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib	fragmentation; HE projectiles; grenades
Total No. of Fragments: For TNT For Subject HE	Method of Loading: Cast
	Loading Density: gm/cc 1.71
Fragment Velocity: ft/sec At 9 ft At 25½ ft	Storage:
Density, gm/cc	Method Dry
Blast (Relative to TNT): (d)	Hazard Class (Quantity-Distance) Class 9
Air: Peak Pressure 111 Impulse 126	Compatibility Group Group I Exudation
Energy	
Air, Confined: Impulse	Preparation: See Composition B Origin: Developed by the British between World Wars I and II and standardized in the United States early in World War II.
Under Water: Peak Pressure	Black Modulus at Room Temperature (25°-30°C):
Impulse Energy	Dynes/cm ² x 10-10 3.09 Density, gm/cc 1.74
Underground: Peak Pressure	Absolute Viscosity, poises:* Temp, 85°C 210** 90°C
Impulse	Efflux Viscosity, Saybolt Seconds:
Energy	Temp, 85°C 9-14
	 Compositions using Spec Grade Type A, Class A RDX. Composition prepared using RDX of optimum particle size.

Composition:	Molecular Weight:	224			
70 RDX 70 INT 30	Oxygen Balance: CO ₂ % CO%	- 37 - 8			
and the second sec	Density: gm/cc Cast	1.71			
	Melting Point: °C	ing of The oblighter			
C/H Ratio	Freezing Point: °C	Tring the South Description			
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus cm 60	Boiling Point: °C	A PACING MILLION			
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 14 Sample Wt, mg 20	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀			
Friction Pendulum Test:	Vacuum Stability Test:	A Starting and			
Steel Shoe Unaffected Fiber Shoe Unaffected	cc/40 Hrs, at 90°C				
Rifle Bullet Impact Test: Trials Kalence Stress St	100°C 120°C 135°C 150°C	0.86			
Burned 0 Unaffected 40	200 Gram Bomb Sand Test: Sand, gm 56.6				
Explosion Temperature: °C	Sensitivity to Initiation:				
	Mercury Fulminate	0.21*			
5 Decomposes 265	Lead Azide Tetrvl	0.20*			
15	*Alternative initiating char Ballistic Mortar % TNT: (a)	ges.			
20	Trauzi Test. % TNT:	132			
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: (b) Method	в			
100°C Heat Test:	Condition	Cast			
% Loss, 1st 48 Hrs 0.07	Confined	No			
% Loss, 2nd 48 Hrs 0.08	Density, gm/cc	1.725			
Explosion in 100 Hrs None	Brisance, % TNT	136			
Flammability Index:	Detonation Rate: Confinement	None			
Hygroscopicity: % Nil	Condition Charge Diameter, in.	Cast 1.0			
Volatility: Nil	Density, gm/cc Rate, meters/second	1.73 8060			

Fragmentation Test:		Shaped Charge Effectiveness, TNT = 100:		
90 mm HE, M71 Projectile, Lot WG Density, gm/cc	C-91:	Glass Cones Hole Volume Hole Dooth	Steel Cones (e)	
Charge Wt, Ib	2.213			
Total No. of Fragments: For TNT	703	Color:	Yellow-buff	
For Subject HE	1165	Principal Uses: Shaped cha:	rge bombs;	
3 inch HE, M42A1 Projectile, Lot K	C-5:	especially projectile	fragmentation HE s, grenades	
Density, gm/cc	1.72		in the second second	
Charge Wt, Ib	0.923		anning a' start an	
Total No. of Fragments:		Method of Loading:	Cast	
For TNT	514			
For Subject HE	828	Leading Density on /or	1 71	
	- 191 - 100 C	Loading Density: gm/cc	T·[T di diti	
Fragment Velocity: ft/sec At 9 ft At 251/6 ft		-Storage:		
Density am/cc		hunder a faille an		
Denany, gin/ cc		Method	Dry	
Blast (Relative to TNT):	(d)	Hazard Class (Quantity-Dist	tance) Class 9	
Air:	second of plantaset	Compatibility Group	Group I	
Peak Pressure	110	Freedorff and		
Impulse	120	Exudation		
Energy	0 (4 (0)8.)			
A DECK AND A DECK A DEC		Preparation: See Composi	tion B	
Air, Confined: Impulse		Origin: Developed by the World Wars I and II a the United States ear	British between and standardized in ly in World War II.	
Under Water: Peak Pressure		Absolute Viscosity, pois	es:*	
Impulse		Temp, 85°C		
Energy		90°C Efflux Viscosity, Sevhol	⊃3.2 t Seconds:	
11		Town 8500	string at and st	
Underground:		Temp, 07 C	with the way is a sould be	
		Heat of:		
Energy		Combustion, cal/gm Explosion, cal/gm Gas Volume, cc/gm	2685 1213 854	
		* Composition using Spec	c Grade Type A.	
S. 1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1		Class A RDX.	sition of mixture	
2		** Calculated from compos	sition of mixture.	

Cyclotol, 65/35

Composition:	Molecular Weight:	224		
% RDX 55 TNT 35	Oxygen Balance: CO ₂ % CO %	-140 - 9		
	Density: gm/cc Cast	1.71		
	Melting Point: °C	ment to alk hero?		
C/H Ratio	Freezing Point: °C	SPI transfer and		
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	et California and Anna R		
Sample Wt 20 mg	Refractive Index, n ^D ₂₀			
Picatinny Arsenal Apparatus, in.	n ^D ₂₅			
Sample Wt, mg	n ₃₀			
Friction Pendulum Test;	Vacuum Stability Test:	TRT SHEETS		
Steel Shoe Unaffected	cc/40 Hrs, at			
Fiber Shoe Unaffected	- 100°C			
Rifle Bullet Impact Test: Trials	120°C			
%	135°C			
Explosions	150°C			
Partials				
Burned	200 Gram Bomb Sand Test:	55.4		
Explosion Temperature: °C	Sensitivity to Initiation:			
Seconds, 0.1 (no cap used)	Minimum Detonating Charge, gm			
5 Decomposes 270	Mercury Fulminate			
10	Tetry			
15		A Dr. Constraints		
20	Ballistic Mortar, % TNT: (a)	134		
and the second	Trauzl Test, % TNT:			
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method	Radit Provincial		
100°C Host Tott	Condition			
% Loss 1st 48 Hrs	Confined			
% Loss, 2nd 48 Hrs	Density, gm/cc			
Explosion in 100 Hrs	Brisance, % TNT	and a second		
	- Detonation Rate:	verset 1		
Flammability Index:	Confinement	None		
Museessatilituu 0/ Nii 1	- Condition	Cast		
nygroscopicity: 70	Charge Diameter, in.	1.0		
Volatility: Nil	Density, gm/cc	1.72		
	Rate, meters/second	1912		

Cyclotol, 65/35

Fragmentation Test:		Shaped Charge Effectiveness, TNT = 100:		
90 mm HE, M71 Projectile, L	ot WC-91:	Glass Cones	Steel Cones (e)	
Density, gm/cc	1.71	Hole Volume		
Charge Wt, Ib	2.253	Hole Depth	130	
Total No. of Fragments: For TNT	703	Color: Yell	ow-buff	
For Subject HE	1153	Principal Heart Chanad change	e hombs.	
3 inch HE, M42A1 Projectile,	Lot KC-5:	especially f projectiles.	ragmentation HE grenades	
Density, gm/cc	1.71 with the	P0	(* 05 fr + + + + + + + + + + + + + + + + + +	
Charge Wt, Ib	0.922	int a sherai		
Total No. of Fragments:		Method of Loading:	Cast	
For TNT	514	meniou or according.	Poletika Presidant V 22	
For Subject HE	769	Loading Density: am/cc	1.71	
Freemant Valesitus (tr/acc	21991			
At 9 ft			the line indial and	
At 251/2 ft		Storage:		
Density, gm/cc		Method	Dry	
	200 Guya Barris bred Ta			
Blast (Relative to TNT):		Hazara Class (Quantity-Distar	ICE) ULASS 7	
Air:		Compatibility Group	Group I	
Peak Pressure		10.53		
Impulse		Exudation		
Energy		5	n ferdandi C	
		Preparation: See Compositi	lon B	
Air, Confined:		Origin: Developed by the F	British between	
Impulse		World Wars I and II and	standardized in	
Under Water:		the United States early	in World War II.	
Peak Pressure		Futectic Temperature. °C:	79	
Impulse				
Energy		gm RDX/100 gm TNT	1. 16	
		95°C	5.85	
Underground: Peak Pressure		Absolute Viscosity, poises	s:*	
Impulse		0r0a		
Energy		1'emp, 05°C	26.0	
Heat of:	*		CONTRACT OF THE DESIGNATION OF THE OWNER OF THE	
Combustion, cal/gm	2755	* Composition using Spec (Class A RDX.	Grade Type A,	
Explosion, cal/gm Gas Volume, cc/gm * Calculated from compo	1205 845 sition of mixture.	a 1 17	Yolardiiy:	

Composition:	and the party party of	Molecular Weight:	224		
۳٥ אתפ	60	Oxygen Balance:	ent fitter the loos be		
KDA	Contraction of the second		-43		
TNT	40		10		
		Density: gm/cc Cast	1.68		
		Melting Point: °C			
C/H Ratio		Freezing Point: °C	The substance with		
Impact Sensitivity, 2 Kg Wt:	76	Boiling Point: °C	B PERSONAL AND AND C.		
Sample Wt 20 ma	12	Refractive Index p ^D			
Picatinny Arsenal Apparatus, in.	14				
Sample Wt, mg	19	n ₂₅			
	and the second	n ₃₀	Total No. of Property		
Friction Pendulum Test:		Vacuum Stability Test:			
Steel Shoe	Unaffected	cc/40 Hrs, at			
Fiber Shoe	Unaffected	90°C			
Pillo Bullot Impact Test: Trials	an a	— 100°C			
Kine bunet impact rest. Thats		120°C	0.29		
Explosions 5		135°C			
Partials 55		150°C			
Burned 25		200 Gram Bomb Sand Test:			
Unaffected 15		Sand, gm	54.6		
Explosion Temperature: °C	Editorinating Gr	Sensitivity to Initiation:			
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, g	m		
1		Mercury Fulminate	0.22*		
5 Decomposes 280		Lead Azide	0.20*		
10		Tetryl			
15		*Alternative initiating char	rges.		
20		Ballistic Mortar, % TNT: (a)	1.33		
		Trauzl Test, % TNT:			
75°C International Heat Test:		Plate Dent Test: (b)	anary 11 April 1		
% Loss in 40 Hrs		Method	B		
100°C Heat Test:		Condition	Cast		
% Loss, 1st 48 Hrs		Confined	No		
% Loss 2nd 48 Hrs		Density, gm/cc	1.72		
Explosion in 100 Hrs		Brisance, % TNT	132		
		— Detonation Rate:	Verener		
Flammability Index:		Confinement	None		
		- Condition	Cast		
nygroscopicity: %	11	Charge Diameter, in.	1.0		
Volatility	: 1	Density, gm/cc	1.72		
N:	LT.	Rate, meters/second	7900		

Cyclotol, 60/40

Fragmentation Test:		Shaped Charge Effectiveness, TNT =	100:
90 mm HE, M71 Projectile, Lot	WC-91:	Glass Cones Stee	l Cones (e)
Density am/cc	1.65	Hole Volume 178	162
Change M/t Ib	2,187	Hole Depth 125	148
Charge Wt, ID	Contraction of the second		
Total No. of Fragments:		Color: Yel	low-buff
For TNT	703		
For Subject HE	998	Principal Uses: Shaped charge h	pomb;
3 inch HE, M42A1 Projectile, Lo	KC-5:	projectiles, gr	renades
Density, gm/cc	1.67		
Charge Wt, Ib	0.882	ан, 19 _{1,} 17 ал	
Total No. of Fragments:		Method of Loading:	Cast
For TNT	514	N N N N N N N N N N N N N N N N N N N	
For Subject HE	701		1 68
	7510	Loading Density: gm/cc	1.00
Fragment Velocity: ft/sec	(c)		i
At 9 ft	2965	Storage:	
Density and co			
Density, gm/cc	180 10	Method	Dry
Blast (Relative to TNT):	(d)	Hazard Class (Quantity-Distance)	Class 9
A		Compatibility Group	Group I
Peak Pressure	104	1995 LLAN	
Impulse	116	Exudation	
Eperav	deer's liquid	in the second second	
Lineigy		Demonstriant Gas Composition	10
Air, Confined:		Preparation: See composition	Б
Impulse		Origin: Developed by the Bri	tish between
		World Wars I and II and st	andardized in
Under Water:		the United States early in	World War 11.
Peak Pressure		Bulk Modulus at Room	
Impulse		Temperature (25°-30°C):	
Energy		/ 2	the Table States
1. A		Dynes/cm ⁻ x 10	4.14
Underground: Peok Pressure		Densitoy, Buy co	The best plant of
Impulse		Absolute Viscosity, poises:*	
Energy		Town 8500	12.3
Nest of	*	90°C	من معرفة من المراجع ال المراجع المراجع
near or.	2820		
Combustion, cal/gm Explosion, cal/gm	1195 845	* Compositions using Spec Gra Class A RDX.	de Type A,
Gas volume, cc/gm	inch ²	the second stands by the second	
Compressive Strength: 10/	2200-3000		

* Calculated from composition of mixture.

References: 15

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(c) R. W. Drake, Fragment Velocity and Panel Penetration of Several Explosives in Simulated Shells, OSRD Report No. 5622, 2 January 1946.

(d) V. Philipchuk, Free Air Blast Evaluation of RDX-INT-Al, RDX-INT, and INT-Metal Systems, National Northern Summary Report, NN-P-34, April 1956.

(e) Eastern Laboratory, du Pont, <u>Investigation of Cavity Effect. Section III</u>, Variation of Cavity Effect with Composition, NDRC Contract W-672-ORD-5723.

(f) W. S. Cramer, Bulk Compressibility Data on Several High Explosives, NAVORD Report No. 4380, 15 September 1956.

(g) Also see the following Picatinny Arsenal Technical Reports on Cyclotols:

<u>o</u>	크	2	<u>3</u>	<u>14</u>	5	6	<u>7</u>	8	2
1290 1530	1651 1741	1482	1483 1793 1983	1824 1834 1944 2004	1435 1585	1476 1756 1796 1876	1427 1507 1747	1398 1488 1838	1469 1509 1709

(h) C. Lenchitz, W. Beach and R. Valicky, Enthalpy Changes, Heat of Fusion and Specific Heat of Basic Explosives, PATR No. 2504, January 1959.

¹⁵See footnote 1, page 10.

Composition:		Molecular Weight: $(C_3H_6N_6O_3)$	174
[∞] 20.6 H 3.5 ^{0=N-N}	<u>→ n-n=</u> 0	Oxygen Balance: CO. <u>.</u> % CO %	-55 -28
N 48.3 H ₂ C	CH ₂	Density: gm/cc	
0 27.6 N		Melting Point: °C 1	.05 to 107
C/H Ratio 0.12		Freezing Point: °C	et v fal. H
Impact Sensitivity, 2 Kg Wt:	in the set	Boiling Point: °C	
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	15 to 22 17 to 20	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Unaffected Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 0.20	(c)
Rifle Bullet Impact Test: Trials % Explosions Partials		*Average value of 5 gm sample twi lized from isoamyl alcohol.	ce recrystal-
Burned Unaffected		200 Gram Bomb Sand Test:Sand, gm59-	.2 54.1
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 220 10		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetry! **Alternative initiating charges.	0.200** 0.100**
15 20		Ballistic Mortar, % TNT:	130
		Trauzi Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs		Plate Dent Test: Method	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Evaluation in 100 Hrs	8.79 2.98	Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:		- Detonation Rate: Confinement	(b) None
Hygroscopicity: % 30°C, 90% RH	0.02	 Condition Charge Diameter, in. 	Cast 1.2
Volatility:	-	Density, gm/cc Rate, meters/second 7000	1.42 to 7300

Cyclotrimethylene Trinitrosamine

AMCP 706-177

Fragmentation Test:	Shaped Charge Effectiveness, TNT =	100:	
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones Steel	Cones	
Density am/cc	Hole Volume		
Charge Wt. Ib	Hole Depth		
Charge Wit, ib			
Total No. of Fragments:	Color:	Vellow	
For TNT		101101	
For Subject HE	Dringing Hass Transdiant of projectile filler		
3 inch HE, M42A1 Projectile, Lot KC-5:	indiper case. Ingreatents of pr		
Density am/cc	house with the section way by an there is have		
Density, gm/cc	and an and the set of the set of the set of the		
Charge Wt, Ib			
Total No. of Fragments:	Method of Loading. Pressed or g	ast with added	
For TNT	melting poin	t depressants	
For Subject HE		the particular	
the second of the test man of the second second	Loading Density: gm/cc S	ee below	
Fragment Velocity: ft/sec	tta stra stration as build anna sath	le his holer of	
At 9 ft	Storage:	The of the product	
At 25% ft	Storage.		
Density, gm/cc	Method	Dry	
Blast (Relative to TNT):	Hazard Class (Quantity-Distance)	Class 9	
	Compatibility Group	Group M	
Air:	Company Group	Group M	
Peak Pressure	Exudation	None	
Impulse		none	
Energy	Density at Various Pressures.	(b)	
Air. Confined:		ML/CE Mar Herburger	
Impulse	<u>lb/inch²</u>	gm/cc	
all deviced overlanding of an ever an	2.420	1.10	
Under Water:	4,830	1.23	
Peak Pressure	9,650	1.37	
Impulse	14,500	1.44	
Energy	24,200	1.53	
	53,000 42,500	1.59	
Underground:	+2,000	1.77	
Peak Pressure	Heat of:		
Impulse		27.59	
Energy	Combustion, cal/gm	3150	
	Formation, cal/gm	-914	





An ammoniacal solution of an amine is prepared by adding aqueous formaldehyde to ammonium hydroxide. The rate of addition of formaldehyde is regulated to maintain a solution temperature of 30° to 35° C.

Sodium nitrite is dissolved in water and the solution or slurry is then poured into the previously prepared amine-ammonia solution and totally dissolved by stirring. This solution is chilled to below 0° C.

Into a mixed acid solution, previously prepared by dissolving concentrated nitric acid in water and adding concentrated sulfuric acid, all chilled to -9° C, there is added the cold amine-nitrite solution below the surface of the acid mixture. The addition is regulated to take 20 to 30 minutes.

The resulting foamy head of cyclotrimethylene trinitrosamine is allowed to sit over the icy spent liquor for 1/2 hour and is then collected on a sintered glass funnel and washed to neutrality. The moist cyclotrimethylene trinitrosamine is removed from the funnel and air-dried on filter paper. The dry crude product melts at 106° to 107° C. Recrystallization from isoamyl alcohol gives a pure compound melting at 105° to 107° C.

Origin:

Cyclotrimethylene trinitrosamine was discovered in 1888 simultaneously by Griess and Harrow (Ber 21 (1888), p. 2737) and by Mayer (Ber 21 (1888), p. 2883) when sodium nitrite was allowed to react with hexamethylene tetramine in acid solution. This compound was later studied by Duden and Scharff (Ann 288 (1895), p. 218) and by Delépine who determined its heat of formation, which was negative (Bull Soc chim (3) 15 (1896), p. 1199). Because cyclotrimethylene trinitrosamine could be made at first in very poor yield only, it was a long time before it received consideration for practical application as an explosive. However, the study of cyclotrimethylene trinitrosamine was continued and investigations were made as to its behavior in mixtures with other substances (Prof. D. G. Römer "Report on Explosives," BIOSGP 2-HEC 5742).

Destruction by Chemical Decomposition:

Cyclotrimethylene trinitrosamine is easily decomposed by acid or alkali and even by boiling in water.

High Temperature Decomposition, 0.02 gm in 10 ml Test Tube:

(b)

-	Immersed 10 minutes in bath heated at 5°/minute					
		Temp. ^O C				
(1)	Melting begins Decomposition begins Nitrous gas Entire decomposition	105 150 160 170				
(2)	Some bubbles Very slow decomposition Decomposes in 2 minutes Decomposes in 40 seconds Immediate decomposition	110 150 200 250 300				

Long Term Stability:

Cyclotrimethylene Trinitrosamine loosely packed in covered wooden boxes for six years at ambient temperature and protected from the sun:

1. Explosive showed no color change.

(b)

- 2. Melting point decreased from 104.5° to 104°C.
- 3. Coefficient of "Utilisation Practique" decreased from 125.5 to 123.5.
- 4. An Abel Test at 110°C gave no color to iodine starch paper in 15 minutes.

Fusion Tests, Mixtures of Cyclotrimethylene Trinitrosamine and TNT: (b)

Cyclotrimethylene Trinitrosamine, %	Melt: Poin	^{ing} oC	
10 20 30 40 42 50 60 70 95	74 68 62 55 55 61 69 77	(Eutectic)	
60 70 95	95	anti yang tempinya L	

42% Cyclotrimethylene Trinitrosamine 58% TNT 7,000

Reaction of Cyclotrimethylene Trinitrosamine With Other Materials: (b)

1.	Iron powder	Slight reaction
2.	Copper powder	Slight reaction
3.	Aluminum powder	Slight reaction
4.	2 parts picric acid + 1 part R-Salt	 a. Violent decomposition after 2 hours at 10°C b. Violent decomposition after 10 to 15 minutes at 100°C
5.	2 parts nitroglycerin + 1 part R-Salt	No evidence of decomposition after 5 days at 90°C

Detonation Rate: (b)

Confinement	Paper cartridge Pressed 1.18	
Condition		
Charge Diameter, in.		
Rate, meters/second	Density, gm/cc	
5180 5760 6600 7330 7600 7800	0.85 1.00 1.20 1.40 1.50 1.57	

References: 16

(a) Arthur D. Little, Inc. Progress Report No. 106, Fundamental Development of High Explosives, April 1955, Contract No. DAI-19-020-501-ORD(P)-33.

(b) Louis Médard and Maurice Dutour, "Étude Des Proprietés De La Cyclotriméthyléne Trinitrosamine," Mém poudr, <u>37</u>, 1924 (1954).

(c) H. A. Bronner and J. V. R. Kaufman, "Synthesis and Properties of R-Salt," PATR in preparation 1959.

(d) Also see the following Picatinny Arsenal Technical Reports on Cyclotrimethylene Trinitrosamine: 1174, 2179.

16See footnote 1, page 10.

90

DBX (Depth Bomb Explosive)

Composition:	Determined for figure	Molecular Weight:	83
%	and the state of the	Oxygen Balance:	
Ammonium Nitrate	21	CO. %	-46
RDX	21	CO %	-26
INT	40	Density: gm/cc Cast	t 1.68
Aluminum	18	Melting Point: °C	
C/H Ratio		Freezing Point: °C	un contraction
Impact Sensitivity, 2 Kg Wt:	in contract, state (10	Boiling Point: °C	
Bureau of Mines Apparatus, cm	35	Refractive Index	
Picatinny Arsenal Apparatus, in.	13		
Sample Wt, mg	14	n ₂₅	
		n ⁰ ₃₀	The state of sector and sector and
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe		cc/40 Hrs, at	
Fiber Shoe		90°C	
Rifle Bullet Impact Test: Trials		- 100°C	6.35
0/-		120°C	6,15
70 Explosions		135°C	
Partials		150°C	
Burned		200 Gram Bomb Sand Test:	
Unaffected		Sand, gm	58.5
Explosion Temperature: °C		Sensitivity to Initiation:	and the second second
Seconds, 0.1 (no cap used)		Minimum Detonating Char	rge, gm
lowershift as these by the		Mercury Fulminate	
5 Ignites 400		Lead Azide	0.20
10		Tetryl	0.10
20		Ballistic Mortar, % TNT:	(a) 146
		Trauzi Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs		Plate Dent Test:	(b)
		- Method	B Cas+
100°C Heat Test:		Condition	No
% Loss, 1st 48 Hrs			1.76
% Loss, 2nd 48 Hrs		Brisonso 04 TNT	1.10
Explosion in 100 Hrs		Brisance, % TINT	TOE
		— Detonation Rate:	(c) assessment agent
Flammability Index:		Confinement	None
Hyproscopicity: %		- Condition	Cast
Trygroscopicity. 70		Charge Diameter, in.	1.0
Volatility:		Density, gm/cc	1.03
		Rate, meters/second	0000

DBX (Depth Bomb Explosive)

Booster Sensitivity Test: Condition	(e) Cast	Decomposition Equation: Oxygen, atoms/sec	Compression in
Tetryl, gm	100	(Z/sec)	
Wax, in. for 50% Detonation	1.35	Heat, kilocalorie/mole	
Wax, am	a tan ana pilanana ana amin	Temperature Ranae, °C	
Density am/cc	1.76	Phose	
		, hase	
Heat of: Combustion, cal/gm	(d)	Armor Plate Impact Test:	n a an thài an thài an thài an thài an taona an taon
Explosion, cal/gm	1700	60 mm Mortar Projectile:	
Gas Volume, cc/gm		50% Inert, Velocity, ft/sec	
Formation, cal/gm		Aluminum Fineness	
Fusion, cal/gm		El in hijse, i	
		500-lb General Purpose Bombs:	
Specific Heat: cal/gm/°C	(d)		
-5°C, density 1.75 gm/cc	0.25	Plate Thickness, inches	
		11/4	
		11/2	
		13/4	
Burning Kate:			
	and Casell specific Addr.	Bomb Drop Test:	
Thermal Conductivity:	-1	TT 2000 IL Sami Arman Diamina B	
cal/sec/cm/°C	13.2 x 10	17, 2000-ID Semi-Armor-Piercing B	omb vs Concrete:
Density I. () gm/cc	Toda II Shuthan	Max Safe Drop ft	
Coefficient of Expansion:	$\mu = x 10^{-5}$		
Linear, %/ C -13 -17 0	+•) X 10	500-lb General Purpose Bomb vs C	Concrete:
Volume, %/°C		Height ft	
		Trials	
Hardness, Mohs' Scale:		Unoffected	
	with the second state of the	Low Order	
Young's Modulus:	(d)	High Order	
E', dynes/cm ²	10.4×10^{10}	nigh Order	
E, lb/inch ²	1.51 x 10 ⁶	1000-lb General Purpose Bomb vs C	oncrete:
Density, gm/cc	1.72		Hith" C. Hage Yeats
l III (" " " " " " " " " " " " " " " " "	BUMPROD	Height, ft	
Compressive Strength: Ib/inch ² (d)	3210-3380	Trials	
Density 1.78 gm/cc		Unaffected	
Vanar Prossura:	Data Schelinger	Low Order	
°C mm Mercury		High Order	
d w wil			
			an Guildhinos Ca
		de serie des compose angel e p	

DBX (Depth Bomb Explosive)

AMCP 706-177

Fragmentation Test:		Shaped Charge Effectiveness, TNT =	Shaped Charge Effectiveness, TNT $=$ 100:	
90 mm HE, M71 Projectile, I Density, gm/cc Charge Wt, Ib	Lot WC-91:	Glass Cones Ste Hole Volume Hole Depth	el Cones	
Total No. of Fragments: For TNT		Color:	Gray	
For Subject HE		Principal Uses:	Depth charge	
3 inch HE, M42A1 Projectile Density, gm/cc Charge Wt, lb	, Lot KC-5:			
Total No. of Fragments: For TNT For Subject HE		Method of Loading:	Cast	
101 500 jett 112		Loading Density: gm/cc	1.61-1.69	
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	(d) 118 127 138 136	Storage: Method Hazard Class (Quantity-Distance Compatibility Group Exudation <u>Preparation:</u> DBX can be manufactured to water-wet RDX to molten TNT jacketed kettle equipped wit all the water has evaporated is added and with heating an tinued, grained aluminum is ture is cooled with stirring maintain uniformity and when ing the mixture is cast. Di by adding 21% ammonium nitra num to 42% cyclotol or Compo RDX/TNT content plus 19% of melted at about 100°C.	Dry) Class 9 Group I oy slowly adding melted in a steam- th a stirrer. When 1, ammonium nitrate added. The mix- 3 continued to a suitable for pour- 3X can also be made ate and 18% alumi- osition B of 50/50 TNT previously	
			oranitati anti	

93

Origin:

DBX was developed and used by the United States and Great Britain during World War II.

References: 17

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(c) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.

M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.

(d) Philip C. Keenan and Dorothy Pipes, <u>Table of Military High Explosives</u>, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(e) L. C. Smith and S. R. Walton, <u>A Consideration of RDX/Wax Mixtures as a Substitute for</u> Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(f) Also see the following Picatinny Arsenal Technical Reports on DBX: 1585 and 1635.

¹⁷See footnote 1, page 10.

1,3-Diamino-2,4,6-Trinitrobenzene (DATNB)

Composition:	Molecular Weight: $(C_{6}H_{5}N_{5}O_{6})$	243
c 29.6 NH_2 H 2.1 $O_2N \rightarrow NO_2$	Oxygen Balance: CO ₂ % CO %	All and Si
N 28.8	Density: gm/cc Crystal	1.83
0 39.5 NO ₂	Melting Point: °C (a)	290
C/H Ratio 0.380	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 18 Sample Wt, mg 9	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C	17. 12. 1 17. 12. 1 17. 12. 1
Rifle Bullet Impact Test: Trials %	100°C 120°C 135°C	
Partials	150°C	na shirint
Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm	46.6
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	0.20 0.10
20	Ballistic Mortar, % TNT:	100
20	Trauzi Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method	neth <mark>naista</mark> anh limh
100°C Heat Test: 0.00 % Loss, 1st 48 Hrs 0.00 % Loss, 2nd 48 Hrs 0.4	Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:	Detonation Rate: Confinement	None
Hygroscopicity: %	 Condition Charge Diameter, in. Density, gm/cc 	Pressed 0.5 1.65
Volatility:	Rate, meters/second	7500

1,3-Diamino-2,4,6-Trinitrobenzene (DATNB)

Fragmentation Test:	Shaped Charge Effectiveness, TNT $=$ 100:
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones Steel Cones Hole Volume
Charge Wt, Ib	Hole Depth
Total No. of Fragments:	Color: Yellow
For TNT	Cold Bartis 1, 100 S
3 inch HE, M42A1 Projectile, Lot KC-5:	Principal Uses:
Density, gm/cc Charge Wt, Ib	names a state of the second se
Total No. of Fragments: For TNT	Method of Loading: Pressed
For Subject HE	Loading Density: gm/cc
Fragment Velocity: ft/sec At 9 ft At 25½ ft	Storage:
Density, gm/cc	Method Dry
Blost (Relative to TNT):	Hazard Class (Quantity-Distance)
Air: Pook Pressure of Charlen, gen	Compatibility Group
Impulse	Exudation None
Air, Confined: Impulse	<u>Cook-Off Temperature:</u> ^O C 320 Time, minutes 8
Under Water: Peak Pressure	Heat of: Explosion, cal/gm 2876
Impulse et adore	30 a visit share Total
Livergy Loverthe	🖓 - Sec. 9 - Sec. 9 - Sec. 9
Underground: Peak Pressure	Mini Lastri (243) Hits Litter (247)
Impulse and address	1989
a several de la construction de	20 20
	Myannicourthy, Ju
	Valaelety.

Preparation:

Fifty grams (50 gm) of dry styphnic acid was added to 200 gm of anhydrous pyridine with stirring. The resulting slurry was stirred for an additional 30 minutes. The yellow product, dipyridinium styphnate, was collected by filtration and washed with approximately 100 milliliters of diethyl ether. The product was dried over phosphorus (V) oxide, at room temperature, for 5 hours. Yield of 77 gm (94%), melting point 168° to $170^{\circ}C$ (literature melting point $173^{\circ}C$).

To 50 milliliters of phosphorus oxytrichloride, 29.8 gm of the dipyridinium styphnate were added in small portions, with stirring. The reaction mixture was then warmed on a steam bath for 15 minutes. This solution was quenched in 500 gm of ice water. The light yellow precipitate was separated by filtration and washed with water until the washing was neutral to litmus. Yield of 1,3-dichloro-2,4,6-trinitrobenzene 20.4 gm (98%), MP 130° to 131°C (literature MP 128°C).

A suspension of 3 gm of 1,3-dichloro-2,4,6-trinitrobenzene in 9 milliliters of absolute methanol was prepared. This slurry was cooled to 0° C, and dry ammonia was bubbled into the stirred suspension. After 20 minutes the reaction mixture was allowed to warm to room temperature, filtered by suction and washed with methanol and ether until a negative Beilstein test for chloride ion was obtained on the washings. Yield of 1,3-diamino-2,4,6-trinitrobenzene 2.5 gm (97%), MP 288° to 290°C (literature MP 285°C).

Origin:

DATNB, also called 2,4,6-trinitro-1,3-diamino-benzol or 2,4,6-trinitro-phenylenediamine-(1,3), was first obtained by Noelting and Collin in 1884 (Ber <u>17</u>, 260) and also by Barr in 1888 (Ber <u>21</u>, 1546) from 2,4,6-trinitroresorcin dimethylether in contact with ammoniacal alcohol for several days. J. J. Blanksma obtained the same product in 1902 by reacting either 2-chloro-2,4,6-trinitroanisole or 3-chloro-2,4,6-trinitrophenetol with ammoniacal alcohol (Rec trav chim <u>21</u>, 324) and from 2,4,6-trinitroresorcin methylethyl ether with ammoniacal alcohol (Rec trav chim <u>27</u>, 56 (1908)).

Meisenheimer and Patzig in 1906 prepared DATNB in the form of yellow needles, MP 280°C from 1,3,5-trinitrobenzene hydroxylamine and sodium methylate in methyl alcohol (Ber <u>39</u>, 2540). The product was slightly soluble in glacial acetic acid but poorly soluble in other solvents. It decomposed into NH₃ and 2,4,6-trinitroresorcin when boiled with dilute NaOH or KOH (Beil <u>13</u>, 60).

Körner and Contardi prepared DATNB by the reaction of either 2,4-dichloro-1,3,5-trinitrobenzene or 2,4-dibromo-1,3,5-trinitrobenzene with ammoniacal alcohol at room temperature or better by heating to 100°C (Atti R. Accad Lincei (5), 171, 473 (1908)); (5) 18 I, 101 (1909)). A method of preparation by prolonged reaction of N-nitro-N-methyl-2,3,4,6-tetranitroaniline with a saturated ammonia solution was reported in 1913 by van Romburgh and Schepers (Akad Amsterdam Versl 22, 297).

C. F. Van Duin obtained DATNB melting at 301°C by reacting a concentrated aqueous ammonia solution with N-nitro-N,N,N-trimethyl-2,4,6-trinitrophenylenediamine-(1,3) or with N-nitro-N-methyl-N-phenyl-2,4,6-trinitrophenylenediamine-(1,3) (Rec trav chim <u>38</u>, 89-100 (1919)). Later Van Duin and Van Lennep reacted concentrated aqueous ammonia with 2,4,6-trinitro-3-aminophenetol to obtain DATNB melting at 287° to 288°C (Rec trav chim <u>39</u>, 147-77 (1920)). In 1927 Lorang prepared the same compound by boiling 2,4,6-trinitro-1,3-bis (-nitroethyl ureido) benzene with water or by heating it with ammoniacal alcohol in a tube at 100°C (Rec trav chim <u>46</u>, 649) (Beil E <u>17</u>, E II 33).

A recent report describes the preparation of DATNB in two steps from commercially available starting materials. First m-nitroaniline was nitrated with $\rm H_2SO_4-HNO_3$ acid mixture to tetranitroaniline. The crude tetranitroaniline was converted by methanolic ammonia to diaminotrinitro-benzene in a high degree of purity. A conversion of 100 parts of m-nitroaniline into 110 parts of DATNB was obtained by this method, which can easily be carried out on a commercial scale.

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Diazodinitrophenol

Composition:	Molecular Weight: (C6H2N405)	210
% C 34.3 H 0.9	Oxygen Balance: CO2 % CO %	-61 -15
N 26.7 O_2^{N} NO ₂ O_2^{N} NO ₂ O_2^{N} NO ₂	Density: gm/cc Crystal	1.63
0 38.1	Melting Point: °C	157
C/H Ratio 1.056	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	and Billionia
Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 4; (1 1b wt) 7 Sample Wt, mg 15	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	ana antanan Latin angan Alaman angan
Friction Pendulum Test:	Vacuum Stability Test:	
Steel ShoeDetonatesFiber ShoeDetonates	cc/40 Hrs, at 90°C	7 6
Rifle Bullet Impact Test: Trials % Explosions	- 100°C 120°C 135°C 150°C	1.0
Burned Unaffected	200 Gram Bomb Sand Test: Sand gm Black powder fuse	47.5 45.6
Explosion Temperature:°CSeconds, 0.1 (no cap used)11200519510180	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	0.20 0.10
15	Ballistic Mortar, % TNT: (a)	97
angladen het standen unterster in state	Trauzi Test, % TNT:	manifel (sheet)
75°C International Heat Test: % Loss in 48 Hrs 100°C Heat Test: % Loss, 1st 48 Hrs 2.10 % Loss, 2nd 48 Hrs 2.20 Explosion in 100 Hrs None	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	Prink Prinkin Principa Donala Donala Poble Donana
Flammability Index:	- Detonation Rate: Confinement	menera-
Hygroscopicity: % 30°C, 90% RH 0.04	- Condition Pr Charge Diameter, in.	essed
Volatility: 50°C, 30 months Unaffected	Density, gm/cc 0.9 Rate, meters/second 4400 6	1.5 1.6 600 6900

*Until it is established which picramic acid (melting point 169°C) isomer is involved (Ref: J Chem Soc, 2082, August 1949).
AMCP 706-177

Diazodinitrophenol

Fragmentation Test:	Elisten under Versteinigen	Shaped Charge Effectiveness, $TNT = 1$	00:
90 mm HE, M71 Projectile, Density, gm/cc Charge Wt, Ib	Lot WC-91:	Glass Cones Steel (Hole Volume Hole Depth	Cones
Total No. of Fragments: For TNT	Andrikay, Rost	Color: Yell	.ow needles
For Subject HE		Principal Uses: Percussi	on cans
3 inch HE, M42A1 Projectil	e, Lot KC-5:		with Autor States
Density, gm/cc		an a	
Charge Wt, Ib		i for all to for a single a life	
Total No. of Fragments:		Method of Loading:	Pressed
For TNT		(BPR)	
For Subject HE	tr - 141 QA Lea Conce	Loading Density: gm/cc Apparent	0.27
Fragment Velocity: ft/sec At 9 ft At 251/2 ft		Storage:	1.14
Density, gm/cc		Method	Under water
Blast (Relative to TNT):	in the second second second lines.	Hazard Class (Quantity-Distance)	Class 9
Air: Peak Pressure		Compatibility Group	
Impulse		Exudation	None
Energy			
Air, Confined:		Solubility:	
Impulse		Soluble in nitroglycerin, n	itrobenzene,
Under Water:		aniline, pyridine, concentrate acid, and in most common organ	d hydrochloric ic solvents.
Peak Pressure		Hart of	
Impulse		Heat OI:	
Underground:		Combustion, cal/gm Explosion, cal/gm	3243 820
Peak Pressure		Gas volume, cc/gm	002
Impulse _		Sensitivity to Electrostatic	b) 0.012
Energy		Discharge, Dures. (U, U.UIE
			en endutionetal9
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		findsath in an	Walatifikyo 77

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Solubility: gm/100 gm of the following	substances:	(c)
----------------------------------------	-------------	----	---

Solubility at 50°C	
Solvent	<u>%</u>
Ethyl acetate Methanol Ethanol Ethylenedichloride Carbon tetrachloride Chloroform Benzene Toluene Petroleum ether Ethyl ether Carbon disulfide	2.45 1.25 2.43 0.79 trace 0.11 0.23 0.15 Insoluble (at 20°C) 0.08 (30°C)
	01000 (30-0)

Preparation: (Chemistry of Powder and Explosives, Davis)



Ten gm of picramic acid is suspended in 120 cc of 5% hydrochloric acid, and under efficient agitation at about 0° C. 3.6 gm sodium nitrite in 10 cc water is dumped into the suspension. Stirring is continued for 20 minutes, the product filtered off and washed thoroughly with ice water. The dark brown product, if dissolved in acetone and precipitated in water, turns brilliant yellow.

Origin:

Discovered by Griess in 1858 (Annalen 106, 123; 113, 205 (1860) and studied extensively by L. V. Clark (Ind Eng Chem 25, 663 (1933). Developed for commercial use in 1928. This compound was patented in the United States by Professor William M. Dane.

Destruction by Chemical Decomposition:

Diazodinitrophenol is decomposed by adding the water-wet material to 100 times its weight of 10% sodium hydroxide. Nitrogen gas is evolved.

References: 18

(a) Philip C. Keenan and Dorothy Pipes, <u>Table of Military High Explosives</u>, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(b) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by

¹⁸See footnote 1, page 10.

Diazodinitrophenol

Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

(c) L. V. Clark, "Diazodinitrophenol, A Detonating Explosive," Ind Eng Chem 25, 663 (1933).

Seidell, Solubilities of Inorganic and Organic Compounds, Van Nostrand and Co., N. Y.

(d) Also see the following Picatinny Arsenal Technical Reports on Diazodinitrophenol:

<u>o</u>	2	<u>4</u>	5	<u>7</u>	8	2
150 610 2120	1352	34 214	355	827	318 1838	2179
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Diethylene Glycol Dinitrate (DEGN) Liquid

Composition:	Molecular Weight: (C4H8N207)	196
C 24.5 $H_2C \longrightarrow ONO_2$ H 4.1 $H_0C \searrow$	Oxygen Balance: CO.: % CO %	-41 - 8
N 14.3 $H_{0}C \rightarrow 0$	Density: gm/cc Liquid	1.38
$0 57.1 \qquad H_{0}C ONO_{0}$	Melting Point: °C	2
C/H Ratio 0.143	Freezing Point: °C	lp) un transition (
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C Decomposes	160
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 9 Sample Wt, mg	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^S ₃₀	1.4498
Friction Pendulum Test: Steel Shoe Explodes Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C	0.200/00.50/00
Rifle Bullet Impact Test: Trials % Explosions Partials	120°C 135°C 150°C	0. 300 20 mr/gm
Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm	42.2
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 237 10 15	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	ng Kin sini di Kasa Bi sa sanati Bi sa sanati Mi
20 berryel based of	Ballistic Mortar, % TNT:	90
75°C Internetional Heat Tests	Trauzl Test, % TNT:	77
75 C International Heat Test: % Loss in 48 Hrs 100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs 3.0 Explosion in 100 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:	Detonation Rate: Confinement	Stated and
Hygroscopicity: %	Condition Charge Diameter, in.	
Volatility: 60°C, mg/cm ² /hr 193	Density, gm/cc Rate, meters/second	1.38 6760

Diethylene Glycol Dinitrate (DEGN) Liquid

Booster Sensitivity Test: Condition	Oxygen, atoms/sec
Tetryl, gm	Heat, kilocalorie/mole
Wax, in. for 50% Detonation	(AH, kcal/mol)
Wax, gm	Temperature Range, °C
Density, gm/cc	Phase
Heat of:	Armor Plate Impact Test:
Combustion, cal/gm	
Explosion, cal/gm	60 mm Mortar Projectile:
Gas Volume, cc/gm 2020	Aluminum Fineness
Formation, cal/gm	Aluminum Prieress
Fusion, cal/gm	500-Ib General Purpose Bombs:
Specific Heat: cal/gm/°C	Plate Thickness, inches
	The second se
	1 III of the Arter
	11/4
	1½
17 O. A	13/4
Burning Rate:	if splant pers
cm/sec	Bomb Drop Test:
Thermal Conductivity: cal/sec/cm/°C	T7, 2000-Ib Semi-Armor-Piercing Bomb vs Concrete
in himing a later of the second s	
Linear, %/°C	500-Ib General Purpose Bomb vs Concrete:
Volume, %/°C	Height, ft
and the second	Trials
Hardness, Mohs' Scale:	Unaffected
Emond Text in 1965.	Low Order
Young's Modulus:	High Order
E', dynes/cm²	 A P 4 receased of
E, Ib/inch ²	1000-Ib General Purpose Bomb vs Concrete:
Density, gm/cc	Haisht ft
	Triale
Compressive Strength: Ib/Inch ²	I rigis
 a statistical sta	
Vapor Pressure: network °C mm Mercury	Low Order High Order
20 0.0036 60 0.130	1. Statestar
	The first second s
	Spin to an international problems

Diethylene Glycol Dinitrate (DEGN) Liquid

AMCP 706-177

Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100:
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones Steel Cones
Density, gm/cc	Hole Volume
Charge Wt, Ib	Hole Depth
Total No. of Fragments:	Color: Colorless
For TNT	(here we are the second s
For Subject HE	Principal Uses: Propellant compositions
3 inch HE, M42A1 Projectile, Lot KC-5:	11251
Density, gm/cc	the second rest without approximit we set
Charge Wt, Ib	- A State of the S
Total No. of Fragments:	Method of Loading:
For TNT	
For Subject HE	Loading Density: gm/cc
Fragment Velocity: ft/sec	
At 9 ft	Storage
Density am/cc	Storage.
Density, gir, ee	Method Liquid
Blast (Relative to TNT):	Hazard Class (Quantity-Distance) Class 9
Air: Peak Pressure	Compatibility Group
Impulse	Exudation
Energy	
Air, Confined: Impulse	Preparation: DEGN can be prepared with approxi mately 85% yield by adding diethyleneglycol to mixed acid (50% HNO ₃ , 45% H ₂ SO ₄ , and 5% H ₂ O). The temperature is kept at 30°C or
Under Water: Peak Pressure	lower. The separated DEGN is purified by washing with successive portions of water,
Impulse	dilute sodium carbonate solution and water
Energy	The Paral of A + 2
Underground:	$ \begin{array}{r} Hydrolysis, & Acid: \\ 10 days at 22°C & 0.003 \\ 5 days at 60°C & 0.003 \end{array} $
Peak Pressure	Solubility in Water, gm/100 gm at.
Impulse Energy	25°C 0.40 60°C 0.60
Viscosity, centipoises:	Solubility, gm/100 gm, at 25°C, in:
	Ether 00 Alcohol 00
1emp, 20 0 0.1	2:1 Ether:Alcohol 00
	Acetone 00

Origin:

First prepared and studied by Wm. H. Rinkenbach in 1927 (Ind Eng Chem 19, 925 (1927) and later by Rinkenbach and H. A. Aaronson (Ind Eng Chem 23, 160 (1931)) both of Picatinny Arsenal. Used in propellant compositions by the Germans during World War II.

Destruction by Chemical Decomposition:

DEGN is decomposed by adding it slowly to 10 times its weight of 18% sodium sulfide (Na₂S·9H₂O). Heat is liberated by this reaction but this is not hazardous if stirring is maintained during the addition of DEGN and continued until solution is complete.

References: 19

See the following Picatinny Arsenal Technical Reports on DEGN:

<u>o</u>	1	2	<u>3</u>	4	6	<u>1</u>	2
50 180 620 1490 1990	231 551 1391 1421	72 602 1282 1392	673 1443	494 1624	346 1516 1616 1786	487 1427 1487 1817	279 579 1439

¹⁹See footnote 1, page 10.

Composition:	Molecular Weight: $(C_1 \cap H_1 \otimes N_1 \cap S_2)$	380
% с 31.6 н 3.2 Снсо ₂ сн ₂ с(No ₂) ₂ сн ₃	Oxygen Balance: CO ₂ % CO %	-59 -17
N 14.7 CHCO _o CH _o C(NO _o) _o CH _o	Density: gm/cc Crystal	1.60
0 50.5	Melting Point: °C Form I Form II	89 86
C/H Ratio	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:Bureau of Mines Apparatus, cm100+Sample Wt 20 mg100+Picatinny Arsenal Apparatus, in.18Sample Wt, mg18	Boiling Point: °C Refractive Index, n ^D ₂₀ n ^D ₂₅	n inn t. Naist
Friction Pendulum Test:		
Steel ShoeUnaffectedFiber ShoeUnaffected	cc/40 Hrs, at 90°C	
Rifle Bullet Impact Test: Trials % Explosions	120°C 135°C 150°C	0.91
Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 4 Smokes 250 10	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	july 1 doet kapini genni
20	Ballistic Mortar, % TNT:	
Sector Sector (Sector Sector Sec	_ Trauzl Test, % TNT:	N SHORE
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:	— Detonation Rate: Confinement	Renard 1
Hygroscopicity: %	Condition Charge Diameter, in.	
Volatility:	Density, gm/cc Rate, meters/second	1.49 6050

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Bis(2,2-Dinitropropyl) Fumarate (DNPF)

Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100:
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Cones Hole Volume Hole Depth
Total No. of Fragments: For TNT	Color: White
For Subject HE	Principal Uses:
3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib	Baaparantii Saarayan yahyy 1987 kogy Innys. Baaparanaa anti Arkiana - Ingganaranaa - Lisa Baaparanaa - Nie – 310 – Lisa Arkianakan musta - Aragananaa - Lisa
Total No. of Fragments: For TNT	Method of Loading: Cast
For Subject HE	Loading Density: gm/cc 1.50
Fragment Velocity: ft/sec At 9 ft At 25½ ft	Storage:
Density, gm/cc	Method Dry
Blast (Relative to TNT):	- Hazard Class (Quantity-Distance)
Air: Peak Pressure	Compatibility Group
Impulse Energy	Exudation None
Air, Confined: Impulse	Heat of: Combustion, cal/gm 3070 (calculated)
Under Water: Peak Pressure	Detonation, cal/gm 767 (calculated) Viscosity, poises:
Impulse Energy Constitution	Temp, 98.9 C 0.586 106.5 C 0.435
Underground: Peak Pressure Impulse	<u>Liquid Density, gm/cc:</u> Temp, 98.9 ^o C 1.382 106.5 ^o C 1.375
Energy	Origin: Synthesized in 1952 by M. E. Hill of the U.S. Naval Ordnance Laboratory, White Oak, Maryland.
Derivative of the second se	Note State

Bis(2,2-Dinitropropyl) Fumarate (DNPF)

AMCP 706-177

Preparation:	(1) Part (1) - resignant	(a, b)		
нс-сосі + 20 нс-сосі	н ₃ с(No ₂) ₂ сн ₂ он	Alcl ₃ , H	с-со ₂ сн ₂ с(No ₂) ₂ сн ₃ -со ₂ сн ₂ с(No ₂) ₂ сн ₃	inen stringen y
3.3 mol fumaryl chloride	7.3 mol 2,2-dinitropropanol	1.6 mol aluminum chloride	83% yield bis(dinitropropyl)	fumarate

Dinitropropanol was mixed with chloroform (1320 milliliters) and the mixture heated to boiling. The distillate was collected in a water separator. At first the distillate was cloudy and this was dried with calcium chloride before being returned to the system. When no more water was collected in the water separator, the mixture was cooled to room temperature and the separator removed. Fumaryl chloride was introduced, followed by the aluminum chloride which was added in four equal portions. Air was blown into the flask for a minute to effect mixing, and the reaction sustained itself without the addition of heat for one hour. Steam was gradually introduced so that the reflux temperature was reached 2-1/2 hours after the beginning of the reaction. After 3 hours of reflux, the hot liquid was poured into a bucket. As cooling took place the slurry was vigorously agitated until it finally set up at room temperature. This material was broken up and mixed with dilute ice cold HCl. The solid product was collected on a sintered funnel, washed with water and with hexane. The crude material was recrystallized from methanol to give a product melting at 86°C (uncorrected), but after storage for several days the melting point was 89°C.

References: 20

(a) M. E. Hill, Preparation and Properties of 2,2-Dinitropropanol Esters, NAVORD Report No. 2497, 3 July 1952.

(b) D. L. Kouba and H. D. McNeil, Jr., Hercules Report on High Explosives, Navy Contract NOrd-11280, Task A, 26 May 1954.

²⁰See footnote 1, page 10.

Bis(2,2-Dinitropropyl) Succinate (DNPS)

Composition:	Molecular Weight: $(C_{10}H_{14}N_{4}O_{12})$	382
% C 31.4	Oxygen Balance: CO ₂ % CO %	-63 -21
н 3.7 сн ₂ со ₂ сн ₂ с(No ₂) ₂ сн ₃	Density: am/cc Crystal	1.51
	Melting Point: °C	86
ο 50.2 CH ₂ CO ₂ CH ₂ C(NO ₂) ₂ CH ₃	Examine Point: °C	
C/H Ratio 0.250		
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	Antonia and an aban we abay ang abay an a abay ang bay ang
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C	0.10
Rifle Bullet Impact Test: Trials % Explosions Partials	120°C 135°C 150°C	- indeks roge - interster (14)
Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm	andra an
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 >>400 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl Ballistic Mortar, % TNT:	alisti-bidi
20	Trauzi Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs 100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Explosion in 100 Hrs Flammability Index:	Detonation Rate: Confinement	
Hygroscopicity: %		
Volatility:	Density, gm/cc Rate, meters/second	

Bis(2,2-Dinitropropyl) Succinate (DNPS)

AMCP 706-177

Fragmentation Test:	Shaped Charge Effectiveness, $TNT = 10$	00:
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel C Hole Volume Hole Depth	Cones
Total No. of Fragments: For TNT	Color:	White
For Subject HE	Principal Uses:	
3 inch HE, M42A1 Projectile, Lot KC-5:	and the second second second second second	
Density, gm/cc	n an	
Charge Wt, Ib	the state in the second second second second second	
Total No. of Fragments:	Method of Loading:	Cast
For Subject HE	and a standard standard strength and a strength of the strengt	
	Loading Density: gm/cc	
Fragment Velocity: ft/sec		
At 9 ft At 251/ ft	Storage:	
Density, gm/cc		
	Method	Dry
Blast (Relative to TNT):	Hazard Class (Quantity-Distance)	
Air: Peak Pressure	Compatibility Group	
Impulse	Exudation	None
Energy		
Air, Confined:	Origin:	
Impulse	Synthesized in 1953 by M. E.	Hill of the
Under Water: Peak Pressure	U.S. Naval Ordnance Laboratory, Maryland.	White Oak,
Impulse		
Energy		
Underground: Peak Pressure		
Impulse		
Energy	김 성장 영국에 가격했다.	

Bis(2,2-Dinitropropyl) Succinate (DNPS)

AM	CP	706	5-177

Preparation:	19		(a)		
2сн ₃ с(NO ₂) ₂ сн ₂ он	+	CH2COCL	AlCl3	сн ₂ соосн ₂ с(NO ₂) ₂ сн ₃ + 2HCl сн ₂ соосн ₂ с(NO ₂) ₂ сн ₃	
dinitropropanol		succinyl chloride	aluminum chloride	bis(2,2-dinitropropyl) succinat	te

A methylene chloride solution of dinitropropanol (0.02 mol in 15 milliliters) was mixed with 0.01 mol of succinyl chloride. To this solution 0.003 mol of crushed anhydrous aluminum chloride was added. It was necessary to cool the reaction vessel due to the vigorousness of the reaction. After 25 minutes at room temperature the reaction solution was refluxed 1-1/2hours. Fine needle-like crystals formed upon cooling and adding hexane. The crystals were slurried in dilute hydrochloric acid and on recrystallization from methanol gave a 93% yield of DNPS (melting point 85° to 85.6° C).

References: 21

(a) M. E. Hill, Synthesis of New High Explosives, NAVORD Report No. 2965, 1 April 1953.

²¹See footnote 1, page 10.

2,2-Dinitropropyl-4,4,4-Trinitrobutyrate (DNPTB)

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Composition:	Molecular Weight: (C7H9N5	0 ₁₂) 355
% C 23.6	Oxygen Balance: CO ₂ %	-29
н 2.5 осн ₂ с(No ₂) ₂ сн ₃	CO %	+2.3
N 19.7 C=0	Density: gm/cc	Crystal 1.68
0 54.2 CH2CH2C(NO3)	Melting Point: °C Form I Form III	11 Form II 95 I 59
C/H Ratio	Freezing Point: °C	St. Insulus via
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	and refers to but the
Bureau of Mines Apparatus, cm Sample Wt 20 ma	Refractive Index. n.D.	
Picatinny Arsenal Apparatus, in.	D	
Sample Wt, mg	- D	
Mutherst of Landling	П ₃₀	Total Margarethy
Friction Pendulum Test:	Vacuum Stability Test:	
Steel Shoe	cc/40 Hrs, at	
Fiber Shoe	90°C	
Rifle Bullet Impact Test: Trials	100°C	0.5
%	120°C	
Explosions	135°C	
Partials	150°C	divanti Arranda
Burned	200 Gram Bomb Sand Test:	
Unaffected	Sand, gm	
Explosion Temperature: °C	Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)	Minimum Detonating Charge	e, gm
	Mercury Fulminate	
5 300	Lead Azide	
	Tetryl	
20	Ballistic Mortar, % TNT:	theaten 2 also
and the second	Trauzl Test, % TNT:	
75°C International Heat Test:	Plate Dent Test:	Barry Phases
	Method	
100°C Heat Test:	Condition	
% Loss, 1st 48 Hrs	Confined	
% Loss, 2nd 48 Hrs	Density, gm/cc	
Explosion in 100 Hrs	Brisance, % TNT	People Pressuane
Elementalità Index.	Detonation Rate:	Service
	Confinement	
Hygroscopicity: %	Condition	
The state of the second st	Charge Diameter, in.	
Volatility:	Density, gm/cc	1.67
	Kate, meters/second	7600

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Fragmentation Test:		Shaped Charge Effectivenes	s, TNT = 100:
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc		Glass Cone Hole Volume	s Steel Cones
Charge Wt, Ib		Hole Depth	
Total No. of Fragments: For TNT For Subject HE		Color:	White
3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib		Principal Uses:	
Total No. of Fragments: For TNT For Subject HE		Method of Loading:	Cast
	27 dak	Loading Density: gm/cc	1.67
Fragment Velocity: ft/sec At 9 ft At 25½ ft		Storage:	Riffe Bolkis
Density, gm/cc		Method	Dry
Blast (Relative to TNT):	rig Sec.?	Hazard Class (Quantity-E	Distance)
Air: Peak Pressure Impulse		Compatibility Group Exudation	None
Air, Confined: Impulse Under Water: Peak Pressure		Heat of: (c) Transition, cal/gm I → III II → I	$ \frac{\text{Solvent}}{6.2} \frac{\text{DMF}}{4.8} $ -16.6 -22.0
Impulse Energy	is where, The effective	Heat of Solution, 30°	<u>ΔH Solution, cal/gm</u>
Underground: Peak Pressure Impulse Energy	t soprat Pertudy (In Behaving Ac	Material Form III Form I Form II	<u>CC1)4</u> <u>DMF</u> 29.5 8.1 35.6 12.8 19.1 -9.1
	Godt Agene Creatinou Creatyn Drot Decetyn gol Hurs, a al og	<u>Origin:</u> Synthesized in 195 U.S. Naval Ordnance L Maryland.	2 by M. E. Hill of the aboratory, White Oak,

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dinitropropyl trinitrobutyrate

(c)

Dinitropropanol, trinitrobutyryl chloride and aluminum chloride were slowly mixed in carbon tetrachloride at 60° C. This mixture was refluxed at 75° C for two hours. After the reaction was completed, the mixture was cooled and the crystalline product separated and purified. Water in the dinitropropanol was removed by azeotropic distillation before the acid chloride was added. The purified product had a melting point of 95° to 96° C.

Crystallographic Data:

Three distinct crystallographic modifications of DNPTB have been observed. These polymorphs have been characterized by means of X-ray diffraction and microscopic observation. Form I crystallizes from solution in carbon tetrachloride, chloroform, acetone, chloroformhexane, acetone-water, or methanol-water at room temperature. Prolonged standing of Form I at room temperature under the mother liquor promotes a transition to Form II. Upon solidification of molten DNPTB, Form II is always observed.

emperature,	Average Rate, sq inch/hour	Standard Deviation	Average Rate, mm/hour
15	0.347	0.036	0.012
20	0.435	0.025	0.128
25	0.452	0.048	0.133
30	0.475	0.049	0.140
35	0.253	0.037	0.075

Linear Rate of Transformation of Form II to Form I (c)

Both Forms I and III gave very erratic sensitivity values. The high temperature polymorph, Form II of DNPTB, gave consistent sensitivity values.

References: 22

(a) M. E. Hill, Preparation and Properties of 2,2-Dinitropropanol Esters, NAVORD Report No. 2497, 3 July 1952.

(b) W. B. Hewson, Hercules Report on High Explosives, Navy Contract NOrd-11280, Task A, 18 October 1954.

(c) J. R. Holden and J. Wenograd, <u>Physical Properties of an Experimental Castable Explo</u>sive 2,2-Dinitropropyl 2,4,4-Trinitrobutyrate DNPTB, NAVORD Report No. 4427, 11 December 1956.

²²See footnote 1, page 10.

2,4-Dinitrotoluene (DNT)

Composition:	Molecular Weight: $(C_7H_6N_2O_4)$	1.82
c 46.3	Oxygen Balance: CO ₂ % CO %	-114 - 53
н 3.3	Density: gm/cc	1.521
N 15.4	Melting Point: °C	71
$0 35.0 $ N_2	Freezing Point: °C	11
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	300
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected Rifle Bullet Impact Test: Triols	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C	0.04
% Explosions 0 Partials 0	135°C 150°C	Lan in mining
Burned 0 Unaffected 100	200 Gram Bomb Sand Test: Sand, gm	19.3
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 310 10	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	0.20 0.25
15 (ALC-0 (ALC-0	Ballistic Mortar, % TNT: (a)	71
20 110.0 120.0	Trauzl Test, % TNT: (b)	64
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method	i amof drei - Mi to II amoi
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Confined Density, gm/cc Brisance, % TNT	<mark>tadoscinens ²⁷)</mark> (n) "Ja de Hi no 2607, 7 Janis
Flammability Index:	- Detonation Rate: Confinement	on a in (a) Test nambro la
Hygroscopicity: % 25°C, 100% RH 0.00	Condition Charge Diameter, in.	
Volatility:	 Density, gm/cc Rate, meters/second 	

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2,4-Dinitrotoluene (DNT)

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Fragmentation Test:	Shaped Charge Effectiveness, $TNT = 100$:			
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones Steel Cones			
Density, gm/cc	Hole Volume			
Charge Wt, Ib	Hole Depth			
Total No. of Fragments:	Color: Yellow			
For TNT				
For Subject HE	Principal Uses: Ingredient of propellant			
3 inch HE, M42A1 Projectile, Lot KC-5:	powder, dynamites and			
Density, gm/cc				
Charge Wt, Ib	The start and and the			
Total No. of Fragments:	Method of Loading: Pressed, extruded or cast			
For TNT	composition			
For Subject HE	Loading Density: gm/cc Variable			
Fragment Velocity: ft/sec	12.160 12.100 14.2.410			
At 9 ft At 25½ ft	Storage:			
Density, gm/cc	Method Dry			
Blast (Relative to TNT):	Hazard Class (Quantity-Distance) Class 12			
Air: Peak Pressure	Compatibility Group Group D			
Impulse	Exudation			
Energy				
Ale Confinede	65.5°C KI Test:			
Impulse				
	Minutes 00+			
Under Water: Peak Pressure	Heat of:			
Impulse	Combustion, cal/gm (b) 1545			
Energy	Thermal Conductivity:			
Underground: Peak Pressure	cal/sec/cm/°C Density 1.322 gm/cc 6.28 x 10 ⁻⁴			
Impulse				
Energy	fight gight find that the			
	and the second sec			
	And in the second s			
	그 화고 못했던 것이 안 다시 한 것이 많은 것이 많은 것이 없다.			

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2,4-Dinitrotoluene (DNT)

Pre	par	ati	on:
	-	-	and the second second

See INT.

Solubility: gm/100 gm of the following substances:

30%				
Ethyl Alcohol	Nitroglyceri	n Wat	ter	
<u>°c</u> <u>%</u>	<u>°C</u> ½	°C	76	
25 0.16 35 0.29	20 30	22 50	0.027 0.037	
45 0.49 55 0.77 60 1.03		100	0.254	
Solubility at 15°C, in:				
Solvent	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	Solvent	<u>%</u>	
CHC13 CC14 CCHC	65.076 2.431 60.644	C ₂ H ₅ OH (absolute) Ether (absolute) Acetone	3.039 9.422 81.901	
То́ІйоІ СН ₃ ОН С2Н5ОН (96%)	45.470 5.014 1.916	Ethyl acetate CS ₂ Pyridine	57,929 2,306 76,810	
- /				

Origin:

Occurs as 75% of the products obtained on the nitration of toluene, the remaining 25% being mainly 2,6-DNT and other isomers of DNT. Also occurs as an impurity in crude TNT obtained by standard manufacturing process. Used in explosive mixtures at least since 1931.

References: 23

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) A. H. Blatt, <u>Compilation of Data on Organic Explosives</u>, OSRD Report No. 2014, 29 February 1944.

(c) Report AC-2861.

(d) Also see the following Picatinny Arsenal Technical Reports on DNT:

<u>o</u>	<u>1</u>	2	<u>3</u>	<u>4</u>	5	6	7	8	2
810 1830	1351 1501 1651 1781 1821 2031 2221	72 372 922 1142 1672 1692	43 233 343 673 1023 1663 1743 2013	394 804 1044 1084 1094 1164 1324 1464 1524 1674 1754 2094	1615 2125	186 1556 1816 1896	97 817 837	768 938 1538	69 149 249 279 779 1749

²³See footnote 1, page 10.

Dipentaerythritol Hexanitrate (DPEHN)

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Composition:	Molecular Weight: (C ₁₀ H ₁₆ N ₆ O ₁₉)	554
% C 21.7 H 2.9 N 15.2 ONO ₂ ONO ₂	Oxygen Balance; CO ₂ % CO%	-26 + 3
0 60.2 CH ₂ CH ₂	Density: gm/cc Crystal	1.63
$ON_2OCH_2\dot{C} - CH_2 - O - CH_2 - \dot{C}CH_2ONO_2$	Melting Point: °C	73.7
C/H Ratio 0.154 ONG2 ONG2	Freezing Point: °C	4 feetal with man
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	1.125 M. J.M. Just C
Bureau of Mines Apparatus, cm 14 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 4 Sample Wt, mg 10	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^{SO}	Deniro, generation Generate Witzen Tablet Mar. of Penna
Friction Pendulum Test:	Vacuum Stability Test;	THE
Steel ShoeExplodesFiber ShoeUnaffected	cc/40 Hrs, at 90°C	
Rifle Bullet Impoct Test: Trials % Explosions	100°C 120°C 135°C	3.7 11+
Partials	150°C	
Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm	57.4
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 300 5 Explodes 255 10 15	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	Ale Neak Pressure Invalae Foregy
20	Ballistic Mortar, % TNT: (a)	142
	Trauzi Test, % TNT: (b)	128
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method	Desk Witterrure. Imjechni
100°C Heet Test: % Loss, 1st 48 Hrs 0.11 % Loss, 2nd 48 Hrs 0.10 Explosion in 100 Hrs None	Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index;	Detonation Rate: (c) Confinement	Copper tube
Mygroscopicity: % 0.03	Condition Charge Diameter, in.	Pressed 0.39
Yolatility:	Density, gm/cc Rate, meters/second	1.59 7410

Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100:
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc	Glass Cones Steel Cones Hole Volume
Charge Wt, Ib	Hole Depth
Total No. of Fragments: For TNT	Color: White
For Subject HE	Principal Uses: Ingredient of priming
3 inch HE, M42A1 Projectile, Lot KC-5:	compositions and descent the second sec
Density, gm/cc	Barradar et Berenet en restary et al. Restarde Mar 20
Charge Wt, Ib	Finnhants Areither Ar
Total No. of Fragments:	Mathad of Loading
For TNT	Mernod of Loading:
For Subject HE	E Province and Annual
0	Loading Density: gm/cc
Fragment Velocity: ft/sec	At 3000 to 4000 psi 1.59
At 251/2 ft	Storage:
Density, gm/cc	Method Dry antro9
Blast (Relative to TNT):	Hazard Class (Quantity-Distance) Class 9
Air: Peak Pressure	Compatibility Group
Impulse	Exudation
Energy	pend provide the second s
Air, Confined: Impulse	Preparation: (Chemistry of Powder and Explosives, Davis)
Under Water: Peak Pressure Impulse	$\begin{array}{ccc} 2(\text{HO-CH}_2)_{4}\text{C} & \underline{\text{Dehydration}} \\ (\text{HO-CH}_2)_{3}\text{C-O-C}(\text{CH}_2-\text{OH})_{3} & \longrightarrow \\ (\text{O}_2\text{NO-CH}_2)_{3}\text{C-O-C}(\text{CH}_2-\text{ONO}_2)_{3} \end{array}$
Energy	Dipentaerythritol Hexanitrate is procured
Underground: Peak Pressure	in the pure state (melting point 72°C) by fractional crystallization of crude PETN from moist acetone.
Impulse	Origin: Formed as an impurity in the prepa-
Energy	ration of PETN. Properties first described by W. Frederick and W. Brun in 1930 (Berichte 63, 2861 (1930); Z. ges Schiess- Sprengstoffy 27, 72-6, 125-7, 156-8 (1932))
Dieseriu - A	Sprengsouri <u>21</u> , 13-0, 12)-1, 190-0 (1932))
51/mp.	Heat of:
etars (active constraints)	Combustion, cal/gm 2260 gdddalaw

(b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(c) L. C. Smith and S. R. Walton, <u>A Consideration of RDX/Wax Mixtures as a Substitute for</u> Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(d) F. W. Brown, D. H. Kusler and F. C. Gibson, <u>Sensitivity of Explosives to Initiation</u> by <u>Electrostatic Discharges</u>, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

(e) Various sources in the open literature.

(f) Also see the following Picatinny Arsenal Technical Reports on Explosive D:

<u>0 1</u>	<u>2</u> <u>3</u>	4	5	6	<u>7</u>	8	2	
340 1441 870 1651 1380	132 843 582 1172 1352 1372	694 704 874 1234 1724	65 425 1585 1655 1725	266 556 796 986 1466	1737 1797	328 838 1838	1729 1759	
	1492		1885 1895	1796			rtion Postdardyn Anto Shua Enwr Sonn	

Composition:	Molecular Weight: (C ₆ H ₉ N ₃ O ₁₁)	299
C 24.1 0 0NO ₂	Oxygen Balance: CO ₂ % CO %	-30
$\begin{array}{c} n & 5.0 & cn_2 & 0 & c-ch & ch_3 \\ 1 & 2 & 0 & 0 \\ N & 14.1 & CH & 0 & 0 \\ \end{array}$	Density: gm/cc Liquid	1.47
$CH_2 - ONO_2$	Melting Point: °C	$(m,k^{*}) \in I_{-}(h)$
C/H Ratio 0.180	Freezing Point; °C	- (d) k (2)
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	1.464
Friction Pendulum Test:	Vacuum Stability Test:	an a sharan a sharan a sharan a sh
Steel ShoeUnaffectedFiber ShoeUnaffected	cc/40 Hrs, at 90°C	
Rifle Bullet Impact Test: Trials % Explosions Partials	100°C 120°C 135°C 150°C	5.9
Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm	13.1
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 223 10	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
20	Ballistic Mortar, % TNT:	
	Trauzi Test, % TNT:	
 75°C International Heat Test: % Loss in 48 Hrs 	Plate Dent Test: Method	
100°C Heat Test: 2.5 % Loss, 1st 48 Hrs 2.5 % Loss, 2nd 48 Hrs 1.8 Explosion in 100 Hrs None	Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:	Detonation Rate: Confinement	
Hygroscopicity: %	Condition Charge Diameter, in.	
Volatility: 60°C, mg/cm ² /hr 28	Density, gm/cc Rate, meters/second	

Fragmentation Test:	Shaped Charge Effectiveness, TNT =	100:
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb	Glass Cones Stee Hole Volume Hole Depth	I Cones
Total No. of Fragments: For TNT	Color:	anna a thaile an taraiste anna a thaile a thaile an ta
For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib	Principal Uses: Gelatinizer for n	nitrocellulose
Total No. of Fragments: For TNT For Subject HE	Method of Loading:	to offer offer of the main chart, the propriet
Fragment Velocity: ft/sec	Loading Density: gm/cc	
At 9 ft At $25\frac{1}{2}$ ft	Storage:	and the first state
Density, gm/cc	Method	Liquid
Blast (Relative to TNT):	Hazard Class (Quantity-Distance)	Class 9
Air: Peak Pressure Impulse Energy	Compatibility Group Exudation	
Air, Confined: Impulse	Hydrolysis, % Acid: 10 days at 22°C 5 days at 60°C Solubility in Water	0.021 0.014
Peak Pressure Impulse Energy	$\frac{gm/100 \text{ gm, at:}}{25^{\circ}\text{C}}$	<0.01 <0.015
Underground: Peak Pressure Impulse Energy	at 25 ^o C, in: Ether 2:1 Ether:Alcohol Acetone <u>Heat of:</u>	0) 07
	Combustion, cal/gm	240 (

Preparation:

Glycerol monolactate (GML) is prepared by heating a glycerol lactic acid mixture containing 4% excess lactic acid at 116° C for 112 hours with dry air bubbling through the liquid. The product which contains 0.67% free acid is carefully mixed with 6 parts of 40/60 HNO₃/H₂SO₄ maintained at 20°C, stirred for 1 hour, cooled to 5°C, and poured on ice. It is extracted with ether, water-washed, adjusted to pH 7 by shaking with a sodium bicarbonate solution, and again water-washed three times. It is then dried with calcium chloride, filtered and freed of ether by bubbling with air until minimal loss in weight is obtained. The product has a nitrate-nitrogen content of 13.43% (theoretical 14.1% N). Another batch, prepared from GML obtained from glycerol-lactic acid containing 6.5% excess glycerol, had a nitrate-nitrogen content of 14.30%, corresponding to a mixture containing 5.5% nitroglycerin. It is not considered practicable to prepare the pure GLTN.

Origin:

The preparation of a nitrated ester of lactic acid and glycerol, by nitrating a glyceryl lactate with nitric and sulfuric acids, for use in explosives, was reported in 1931 by Charles Stine and Charles Burke (U. S. Patent 1,792,515).

The preparation of glycerol monolactate by heating glycerol with equimolar proportions of a lactic acid ester of an alcohol boiling below $100^{\circ}C$ (ethyl lactate) was patented by Richie H. Locke in 1936 (British Patent 456,525 and U. S. Patent 2,087,980).

Reference: 31

(a) P. F. Macy and A. A. Saffitz, <u>Explosive Plasticizers for Nitrocellulose</u>, PATR No. 1616, 22 July 1946.

³¹See footnote 1, page 10.

Glycol Dinitrate (GDN) Liquid

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Composition:	Molecular Weight: $(C_2H_4N_2O_6)$	1.52
го с 15.8 ОНО ₂ н 2.6 СН ₂	Oxygen Balance: CO ₂ % CO %	0.0 21
N 18.4	Density: gm/cc Liquid, 25 ^o C	1.48
0 63.2 CH ₂	Melting Point: °C	-20
C/H Ratio 0.092	Freezing Point; °C	(† magui di
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	2 Ipin Mil Price
Bureau of Mines App aratus, cm 4 (1 1b wt); 56 Sample Wt 20 mg Picatinny Arsenal App aratus, in. Sample Wt, mg	Refractive Index, n ^D ₂₀ n ^D ₂₅	1.4452
and the best states	N	Tone be, of Page
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C	For (Chiesen-For
Rifle Bullet Impact Test: Trials % Explosions	- 100°C 120°C 135°C	
Partials Partials	150°C	
Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Explodes 257 10	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	Miller Den de Propriese Propriese Chapters
15	Ballistic Mortar, % TNT:	delado-
20	Trauzi Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method	<u>Alaska Vinner.</u> Mante Alaskan Alaska
100°C Heat Test:	Condition Confined	
% Loss, 1st 48 Hrs	Density, gm/cc	
Explosion in 100 Hrs	Brisance, % TNT	linmike.
Flammability Index:	- Detonation Rate: Confinement	Glass tube
Hygroscopicity: % 30°C, 90% RH 0.00	- Condition Charge Diameter, in.	Liquid 10
Volatility:	- Density, gm/cc Rate, meters/second	1.485 7300 and 2050

Fragmentation Test:	Anderster Weight: 17, 1, 2	Shaped Charge Effectiveness,	TNT = 100: meintegene 3
90 mm HE, M71 Projectile, Density, gm/cc	, Lot WC-91:	Glass Cones Hole Volume	Steel Cones
Charge Wt Ib		Hole Depth	
charge (rtt) is			
Total No. of Fragments:			
For TNT		Color:	Yellow
For Subject HE			
		Principal Uses: Ingredie	nt of nonfreezing
3 inch HE, M42A1 Projecti	e, Lot KC-5:		
Density, gm/cc			
Charge Wt, Ib		mi i the	
			p m pW kinpresi
Total No. of Fragments:		Method of Loading:	
For TNT			
For Subject HE			
and their filtraneous fractions is house		Loading Density: gm/cc	
-	2010	a more that have been a first the second	
Fragment Velocity: ft/sec			A State of the second stat
At 251% ft		Storage:	
Density am/cc		_	
		Method	Liquid
Blast (Relative to TNT):	- 200 Gray Brack Street France	Hazard Class (Quantity-Dist	conce) Class 9
and along the second of the second		Compatibility Group	
Air: Peak Pressure		Company Group	
Impulse		Exudation	
Francisc			
Energy			is t
Air Confined:		Solubility in 1000 cc W	ater:
Impulse	Ballissie Mandres, St. 7347)	Temp, ^o C	Grams
ales econor principation as estimated as a sub-		15	6.2
Under Water:	Tist of Broth Laward	20	6.8
Peak Pressure	Plate Dock Taxi	50	9.2
Impulse		Viscosity, centipoises:	
Energy	Constitute of	Temp, 20 ⁰ C	4.2
	have been 2	Vapor Pressure:	
Peak Pressure	Consetty, with it is	°C	mm Mercury
Impulse	GUT of Managerth	0	0.0044
Eperav	 In the Workshop of the State 	20	0.038
Linergy	 Manufacture (1) 	40	0.26
		80	1.3
	netHpuo J	100	22.0
	Charge Dirichter, in	Heat of:	Conniette diffe
	Generativ, grovine	Combustion, cal/gm	1764
	have the seture present	Formation, cal/gm (b) 366

Glycol Dinitrate (GDN) Liquid

Preparation:

Glycol dinitrate (ethylene glycol dinitrate, dinitroglycol, nitroglycol, dinitrodimethyleneglycol) may be prepared by nitration of ethylene glycol, HOCH₂CH₂OH, with a mixed nitric acid in the same apparatus that is used for the preparation of nitroglycerin. The glycol is prepared by synthesis from ethylene, and ethylene chlorohydrin:



Origin:

Henry was the first to prepare and identify glycol dinitrate (Ber 3, 529 (1870) and Ann chim phys [4] 27, 243 (1872) but Kekulé had previously nitrated ethylene and obtained an unstable oil which he supposed to be glycol nitrate-nitrate. No immediate practical use was made of glycol dinitrate because glycol itself was relatively rare and expensive at the time. It was 1904 before a patent was granted covering the use of GDN as an explosive (DRP 179,789), but it was seven years later before its actual use as an explosive was recorded (Mém poudr <u>16</u> (1911) p. 214). The principal physical properties of GDN were determined or recorded by Rinkenbach (Ref b).

References: 32

32See footnote 1, page 10.

(a) Ph. Naoum, <u>Nitroglycerin and Nitroglycerin Explosives</u>, translation, E. M. Symmes, The Williams and Wilkins Company, Baltimore (1928), p. 224.

(b) Wm. H. Rinkenbach, "The Properties of Glycol Dinitrate," Ind Eng Chem 18, 1195 (1926).

(c) Wm. H. Rinkenbach, "Glycol Dinitrate in Dynamite Manufacture," Chem Met Eng, <u>34</u>, 296 (1927).

(d)	Wm.	H.	Rinke	nbach,	App]	Lica	tion	of	the	Vacuum	Stability	Test	to	Nitroglycerin	and	Nitro-
glycerin	. Exp	lo	sives,	PATR	1624	, 27	Augu	ist	1946).	and the second		-			

<u>н-6</u>

Composition:	Molecular Weight:	93
% RDX 45 TNT 30 Aluminum 20	Oxygen Balance: CO ₂ % CO %	-66 -36
D-2 Wax 5	Density: gm/cc Cast	1.74
Calcium Chloride, added 0.5	Melting Point: °C	
C/H Ratio	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	Boiling Point: °C	
Sample Wt 20 mg	Refractive Index, n ^D ₂₀	
Picatinny Arsenal Apparatus, in. (c) 14 Sample Wt. ma	n ^D ₂₅	
	n ₃₀	
Friction Pendulum Test:	Vacuum Stability Test:	r kola kier
Steel Shoe Unaffected	cc/40 Hrs, at	
Fiber Shoe	90°C	0.17
Rifle Bullet Impact Test: Trials (b)	- 100°C	0.41
%	120°C	
Explosions 80	135 C	
Partials	130 C	
Burned	200 Gram Bomb Sand Test:	
Unaffected 20	Sand, gm	49.5
Explosion Temperature: °C (a) Seconds, 0.1 (no cap used)	Sensitivity to Initiation: Minimum Detonating Charge, gm	
1	Mercury Fulminate	
5 610(min) (c)	Lead Azide	0.20
10	Tetryl	0.10
15	Ballistic Mortar, % TNT: (d)	135
	_ Trauzl Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method	
100°C Host Tost	Condition	
VV Criedi lest: 96 Loss let 48 Hrs 0.78	Confined	
% Loss 2nd 48 Hrs 0.00	Density, gm/cc	
Explosion in 100 Hrs None	Brisance, % TNT	
	- Detonation Rate:	(a, b)
Flammability Index:	Confinement	None
Flammability Index:	Confinement - Condition	None Cast
Flammability Index: Hygroscopicity: % 30°C, 95% RH, 7 days 2.01	- Condition Charge Digmeter in	None Cast 1.0
Flammability Index: Hygroscopicity: % 30 ⁰ C, 95% RH, 7 days 2.01 71 [°] C, 95% RH, 7 days 1.77	Confinement Condition Charge Diameter, in. Density, gm/cc	None Cast 1.0 1.71

del della antica; i	Decomposition Equation: Oxygen, atoms/sec	(ground Change 194	ondition
	(Z/sec) Heat kilosolaria/mala	dur	etryl, gm
	(ΔH, kcal/mol)	www.lock.com/while-	/ax, in. for 50% Detonation
	Temperature Range, °C	100 B 408	/ax, gm
	Phase		ensity, gm/cc
an inggali	a al 1. organization	Total -	
	Armor Plate Impact Test:	3972	r or: ombustion, cal/gm
		923	plosion cal/am
	60 mm Mortar Projectile:	733	Gas Volume cc/am
	50% Inert, Velocity, ft/sec	155	and volume, ce, gm
	Aluminum Fineness	10.05	rian cal/am #8°C (b)
	FOO IL Concert Durante Durante	10.25	ision, cal/gm (0 C (b)
	JUV-ID General Furpose Bombs:	(b)	ific Heat: col/am/°C
	Plate Thickness, inches		
		0.269	5-0
	1	0.268	o°c
	11/4	and the second se	
	11/2		
	13/		
	· /•		ing Rote:
	Bamb Dran Tast	. inversel	n/sec
	bomb brop Test:	(2)	
Concrete:	T7, 2000-Ib Semi-Armor-Piercing Bomb vs (1.10×10^{-3}	I/sec/cm/°C 35°C
	Max Safe Drop, ft		ficient of Expansion:
	500-lb General Purpose Bomb vs Concrete:	tent passi	near, Δl /inch
and a shall		40×10^{-4}	5°C
	Height, ft	131×10^{-4}	°C .
	Trials		
	Unaffected		ness, Mohs' Scale:
	Low Order	/ · ·	
	High Order	(b) g	gʻs Modulus:
		9.0 x 10'5	dynes/cm²
	1000-Ib General Purpose Bomb vs Concrete:	1.30 x 10'	lb/inch ²
	•	1.71	nsity, gm/cc
	Height, ft		
	Trials	See below	pressive Strength: Ib/inch ²
	Unaffected		
	Low Order		r Pressure:
	High Order		°C mm Mercury
	ander 🖌 🖌 de la generation de la companya de	1083	ressive Strength. 1b/inch2
		1.71	ensity, gm/cc
		1.32	timate deformation, %
	1000-Ib General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order	9.0 x 10 1.30 x 10 1.71 See below 1083 1.71 1.32	b/inch ² insity, gm/cc pressive Strength: lb/inch ² or Pressure: °C mm Mercury pressive Strength: lb/inch ² insity, gm/cc timate deformation, %

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н-б

Fragmentation Test:	Shaped Charge Effectiveness, $TNT = 100$:
90 mm HE, M71 Projectile, Lot EGS-1-17: Density, gm/cc Charge Wt, lb	Glass Cones Steel Cones Hole Volume Hole Depth
Total No. of Fragments: For Composition B 998	Color: Gray
For Subject HE 714 For 80/20 Tritonal 616	Principal Uses: HE charge
3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc	Gode West year of the second sec
Charge Wt, Ib	Kaskers and Spreich Constraints
Total No. of Fragments: For TNT	Method of Loading: Cast
For Subject HE	Loading Density: gm/cc 1.71
Fragment Velocity: ft/sec At 9 ft At 25½ ft	Storage:
Density, gm/cc	Method Dry Dry
Blast (Relative to TNT): (a)	Hazard Class (Quantity-Distance) Class 9
Air: 3.25" diameter sphere Peak Pressure Δ psi Catenary 25.4	Compatibility Group Group I
Impulse NFOC Pendulum 19.8 Energy	
Air, Confined:	10°C. Marekana, Mahai Secon
Under Water: Peak Pressure	Yameya Asada tika (B.) 181 - Asada Kariston, (B.) 181 - Asara Cariston, (B.)
Impulse Energy	Banatsa ye Asia Danatsa ye Asa
Underground: Peak Pressure	Esmipyeralak Kérengah. Ip/(m.e
Impulse Energy	terminal and
	<pre>///inter-provide contract contract contract contract contract contract contract contract contract contract contract contract contract contract contract contract contract contract contract contract contract contract contract contract contract contract contract contract contract contract contract contract contract contract contract contract contract</pre>

	100 m 100	One-Inc	h Column	Two-Inch Column		
Explosive	Simulated Altitude, Feet	$\frac{Confined}{m/s}$	Unconfined m/s	$\frac{\text{Confined}}{\text{m/s}}$	Unconfined m/s	
ENT,	Ground	6820	6720	6670	5270	
lensity,	30,000	6660	6930(2)	6610	6760(4)	
5	60,000	6800		6520	6400(4)	
	90,000	6810	6720	6550	6610(1)	
Average	Jan Jahren and	6798	6790	6588	6260	
I - 6,	Ground	7190	7360	7340	6870	
lensity,	30,000	7300(2)	7430	7360	7980	
5	60,000	7280	7490	7550	7010	
	90,000	7300(3)	7270	7500	7000	
Average		7268	7385	7438	7215	

Effect of Altitude, Charge Diameter and Degree of Confinement on Detonation Velocity*

*Confined charge in 1/4" steel tube, AISI 1015 seamless, 1" diameter 18" long, and 2" diameter 7" long. All means were determined from sets of five values unless otherwise indicated by (). A 26 gm tetryl booster was used to initiate each charge.

Average Fragment Velocities at Various Altitudes* (e)

- <u>6</u> -1		Simulated Altitude, Feet			
Explosive	Charge Diameter, Inches	$\frac{\text{Ground}}{\text{m/s}}$	<u>30,000</u> m/s	60,000 m/s	<u>90,000</u> m/s
TNT, density, gm/cc 1.51	1 2	2940 3623	2991 4191	3119 5077	2868 4980
H-6, density, gm/cc 1.71	1 1	3461 4603	3405 4726	3467 4998	3563 5288

*Outside diameter 2.54"; inside diameter 2.04"; length 7".

References:

See HBX-1; HBX-3 reference list.

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Haleite (Ethylene Dinitramine) (EDNA)

(In recognition of its development as a military explosive by the late Dr. G. C. Hale of Picatinny Arsenal.)

Composition:	Molecular Weight: $(C_2H_6N_4O_4)$	150
$\begin{array}{c} & 16.0 \\ H & 4.0 \end{array}$	Oxygen Balance: CO ₂ % CO %	-32 -10.5
N 37.3	Density: gm/cc Crystal	1.71
0 42.7 H C NO ₂	Melting Point: °C Decomposes	175+
C/H Ratio 0.066	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 14 Sample Wt, mg 17	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	in it, ¹⁰ , in it ¹
Friction Pendulum Test:	Vacuum Stability Test:	
Steel ShoeUnaffectedFiber ShoeUnaffected	cc/40 Hrs, at 90°C	
Pilla Bullet Impact Tests Trials	- 100°C	0.5
	120°C	1.5
Explosions 0	135°C	
Partials 60	150°C	11+
Burned 20 Unaffected 20	200 Gram Bomb Sand Test: Sand, gm	52.3
Explosion Temperature:°CSeconds, 0.1 (no cap used)26512165Decomposes1017815173	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	0.21 0.13
20 170	Ballistic Mortar, % TNT: (a)	139
	_ Trauzl Test, % TNT: (b)	122
75°C International Heat Test:% Loss in 48 Hrs0.01	Plate Dent Test: (c) Method	A
100°C Heat Test:	Condition	Pressed
% Loss, 1st 48 Hrs 0.2	Confined	Yes
% Loss, 2nd 48 Hrs 0.3	Density, gm/cc	1.50
Explosion in 100 Hrs None	Brisance, % TNT	122
Flammability Index: 138	- Detonation Rate: Confinement	Unconfined Pressed
Hygroscopicity: % 0.01	Charge Diameter, in.	1.0
Volatility: Nil	Density, gm/cc Rate, meters/second	1.49 7570

Haleite (Ethylene Dinitramine) (EDNA)

AMCP 706-177

	and the second sec		
Booster Sensitivity Test: Condition	(d) Pressed	Decomposition Equation: (e) Oxygen, atoms/sec 10 ^{12.8}	(e) (f) 10 ^{12.1} 10 ^{11.1}
Tetryl, gm	100	(Z/sec)	27 2 20 8
Wax, in. for 50% Detonation	2.09	(ΔH, kcal/mol)	JI.J JU.U
Wax, gm		Temperature Range, °C 184-254	144-164
Density, gm/cc	1.42	Phase Liquid	Solid Solid
		- Chenneering	and the second
Heat of:	1 million	Armor Plate Impact Test:	
Combustion, cal/gm	2477		
Explosion, cal/gm	1276	60 mm Mortar Projectile:	
Gas Volume, cc/gm	908	50% Inert, Velocity, ft/sec	
Formation, cal/gm	134	Aluminum Fineness	
Fusion, cal/gm		500 lb Ganaral Purpose Romber	
C		500-16 General Furpose Dombs.	
Specific Heat: cal/gm/°C		Plate Thickness, inches	
		1	
		11/4	
		11/2	
		- 13⁄4	
Burning Rate:			Seattle attached
cm/sec		Bomb Drop Test:	
Thermal Conductivity:			The second s
cal/sec/cm/°C		T7, 2000-Ib Semi-Armor-Piercing	Bomb vs Concrete:
		- Max Safe Drop ft	
Coefficient of Expansion:		Max Sale Disp, it	
Linear, %/°C		500-Ib General Purpose Bomb vs	Concrete:
Volume, %/°C		Hoight ft	
, , , , , , , , , , ,	1		
Hardness, Mohs' Scale:		Lingfacted	
Young's Modulus:		High Order	
E', dynes/cm²			
E, Ib/inch²		1000-lb General Purpose Bomb vs	Concrete:
Density, gm/cc			Wite and
		– Height, ft	
Compressive Strength: Ib/inch ²		Trials	
		Unaffected	
Vapor Pressure:		Low Order	
°C mm Mercury		High Order	
			and a subscription of the second s

AMCP 706-177

90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.61 Charge Wt, Ib Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc 95/5 Haleite/ Density, gm/cc 1.56 Charge Wt, Ib Total No. of Fragments: For TNT For TNT 514 For Subject HE 600 Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Glass Cor Hole Volume Hole Depth Color: Principal Uses: Wax Method of Loading: Loading Density: gm/cc 5 10 12 1.28 1.38 1.41 Storage:	nes Steel Cones White Booster Pressed psi x 10 ³ 15 20 1.44 1.49
Charge Wt, Ib Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc 1.56 Charge Wt, Ib Total No. of Fragments: For TNT For Subject HE 600 Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Hole Depth Color: Principal Uses: Method of Loading: Loading Density: gm/cc 5 10 12 1.28 1.38 1.41 Storage:	White Booster Pressed psi x 10 ³ 15 20 1.44 1.49
Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: 95/5 Haleite/ Density, gm/cc 1.56 Charge Wt, Ib Total No. of Fragments: For TNT For Subject HE 600	Color: Principal Uses: Wax Method of Loading: Loading Density: gm/cc 5 10 12 1.28 1.38 1.41 Storage:	White Booster Pressed psi x 10 ³ 15 20 1.44 1.49
For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Lot KC-5: <u>95/5 Haleite/</u> <u>95/5 Haleite/</u> <u>1.56</u> Charge Wt, Ib Total No. of Fragments: For TNT 514 For Subject HE 600 Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Wax Method of Loading: Loading Density: gm/cc 5 10 1.28 1.38 1.41 Storage:	Booster Pressed psi x 10 ³ 15 20 1.44 1.49
For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb 7 Total No. of Fragments: For TNT For Subject HE 6 00 7 agment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Principal Uses: Wax Method of Loading: Loading Density: gm/cc 5 10 12 1.28 1.38 1.41 Storage:	Booster Pressed psi x 10 ³ 15 20 1.44 1.49
3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc 95/5 Haleite/ Density, gm/cc 1.56 Charge Wt, Ib Total No. of Fragments: For TNT 514 For Subject HE 600 Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Method of Loading: Loading Density: gm/cc 5 10 12 1.28 1.38 1.41 Storage:	Pressed psi x 10 ³ 15 20 1.44 1.49
Charge Wt, Ib Total No. of Fragments: For TNT 514 For Subject HE 600 Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Method of Loading: Loading Density: gm/cc 5 10 12 1.28 1.38 1.41 Storage:	Pressed psi x 10 ³ 15 20 1.44 1.49
Total No. of Fragments:For TNT514For Subject HE600Fragment Velocity: ft/sec600At 9 ft4251/2 ftDensity, gm/cc51/2 ft	Method of Loading: Loading Density: gm/cc 5 10 12 1.28 1.38 1.41 Storage:	Pressed psi x 10 ³ 15 20 1.44 1.49
For Subject HE 600 Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Loading Density: gm/cc 5 10 12 1.28 1.38 1.41 Storage:	psi x 10 ³ 15 20 1.44 1.49
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Loading Density: gm/cc 5 10 12 1.28 1.38 1.41 Storage:	psi x 10 ³ 15 20 1.44 1.49
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	5 10 12 1.28 1.38 1.41 Storage:	15 20 1.44 1.49
At 25½ ft Density, gm/cc	Storage:	
Density, gm/cc		
	Method	Dry
Blast (Relative to TNT):	Hazard Class (Quantity-	Distance) Class 9
Air: Peak Pressure	Compatibility Group	
Impulse and the second state of the second state	Exudation	None
Energy		
Air Confined		
Impulse		
Under Water: Peak Pressure		
Impulse	a, edd	
Energy		
Underground: Peak Pressure	Att in the second se	
Impulse		
Energy	1.1	
s,		

Compatibility with Metals:

Dry - Copper, brass, aluminum, mild steel, stainless steel, mild steel coated with acidproof black paint, and mild steel plated with copper nickel, cadmium or zinc are unaffected. Magnesium and magnesium-aluminum alloy are slightly affected.

Wet - Copper, brass, mild steel coated with acid-proof black paint, and mild steel plated with copper, cadmium, nickel or zinc are heavily corroded. Aluminum is slightly affected and stainless steel is unaffected.

Impact Sensitivities of Various Crystal Habits:

Bureau	of	Mines	Impact	Test,	2	Kg	Wt:
Habit							cm
lst pla 2nd pla	ate ate						55 55
Bi-pyra Bracydd	ami o ome	1					71 66
Sphenoi	id						46

Solubility: gm/100 gm (%) of:

Water		Alcohol		
°C	%	°c	<u>%</u>	
20	0.25	20	1.00	
40	0.75	40	2.46	
60	2.13	60	5.29	
80	6.38	78	10.4	
LOO	>20			

Preparation:

(Summary Technical Report of the NDRC, Div 8, Vol 1)

$$CH_2O + HCN \rightarrow HO CH_2CN$$

(98% yield)
HO $CH_2CN + NH_3 \rightarrow NH_2CH_2CN + H_2O$
(82% yield)

$$NH_2CH_2CN + 2H_2 \rightarrow H_2N CH_2CH_2NH_2$$

(88% vield)

$$\begin{array}{c} \overset{\mathrm{CH}_2 \longrightarrow \mathrm{NH}_2}{|} & + & \mathrm{Co}_2 \longrightarrow \\ \overset{\mathrm{CH}_2 \longrightarrow \mathrm{NH}_2}{|} & + & \mathrm{Co}_2 \longrightarrow \\ \end{array} \begin{array}{c} \overset{\mathrm{CH}_2 \longrightarrow \mathrm{NH}_2}{|} & & \mathrm{CH}_2 \longrightarrow \mathrm{NH}_2 \end{array}$$

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Haleite (Ethylene Dinitramine) (EDNA)

$$\begin{array}{c} \begin{array}{c} CH_{2} & NH \\ \downarrow \\ CH_{2} & -NH \end{array} \end{array} \xrightarrow{CO} + 2HNO_{3} \end{array} \xrightarrow{CH_{2} - N = NO_{2}} CO + 2H_{2}O \\ \begin{array}{c} CH_{2} - N = NO_{2} \\ CH_{2} - NH - NO_{2} \end{array} \xrightarrow{CH_{2} - N = NO_{2}} CO + 2H_{2}O \\ \begin{array}{c} CH_{2} - N = NO_{2} \\ CH_{2} - NH - NO_{2} \end{array} \xrightarrow{CH_{2} - N = NO_{2}} CO + H_{2}O \end{array} \xrightarrow{CH_{2} - N = NO_{2}} CO + H_{2}O \end{array} \xrightarrow{CH_{2} - N = NO_{2}} CO + H_{2}O \xrightarrow{CH_{2} - N = NO_{2}} CO \xrightarrow{CH_{2} - N = NO_{$$

The raw materials used in this process are cheap and available; the first three reactions proceed smoothly, rapidly and in good yield (70% overall), and only the third requires high pressures. The reaction of ethylenediamine with carbon dioxide at about 220° C and 820 atmospheres has been worked out and is more satisfactory for the preparation of ethyleneurea than the use of chlorethyl carbonate or urea and better than the reaction of acetic anhydride and ethylenediamine to yield N,N'-diacetyl-ethylenediamine which can be treated in a way similar to the above to yield Haleite.

Ethyleneurea is very easily nitrated, with strong nitric acid (98%), at ordinary temperature, and in a very short time, and the dinitroethyleneurea produced appears to hydrolyze, yielding Haleite, immediately after solution in water at 95° C. Both the nitration and hydrolysis are practically quantitative.

Origin:

First described in 1877 by Franchimont and Klobbie (Rec trav chim 7, 17 and 244) but it was 1935 before its value as an explosive was recognized. Standardized during World War II as a military explosive.

Destruction by Chemical Decomposition:

Haleite is decomposed by addition to hot, dilute sulfuric acid. Nitrous oxide, acetaldehyde and ethylene glycol are evolved. Haleite is also decomposed by addition to 5 times its weight of 20% sodium hydroxide.

References: 33

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

- (b) Report AC-2983/Org Ex 179.
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) L. C. Smith and S. R. Walton, <u>A Consideration of RDX/Wax Mixtures as a Substitute for</u> Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(e) R. J. Finkelstein and G. Gamow, <u>Theory of the Detonation Process</u>, NAVORD Report No. 90-46, 20 April 1947.

(f) M. A. Cook and M. Taylor Abbeg, "Isothermal Decomposition of Explosives," University of Utah, Ind Eng Chem (June 1956) pp. 1090-1095.

³³See footnote 1, page 10.

Haleite (Ethylene Dinitramine) (EDNA)

	(g)	Also se	ee the f	ollowing	Picatinn	y Arsena	1 Techn	nical Rep	orts on	Haleite:		
		0	1	2	3	<u>4</u>	5	6	<u>7</u>	8	2	
		1200 1290 1360 1380 1400 1600	1231 1451 1651	1162 1232 1252 1352 1372	1113 1493 1923	414 1294 1434	1255 1325 1395 1885	786 1796	897 1737 1797 1937	1198 1288 1378 1388 1838	1279 1319 1379 1469 1489 2179	
)												

HBX-1

Composition:		Molecular Weight:	102
RDX 40	A	Oxygen Balance:	1
INT 38			-68
Aluminum 17	5472	CO %	- 35
D-2 Wax 5		Density: gm/cc Cast	t 1.72
Calcium Chloride, added 0.5		Melting Point: °C	
C/H Ratio		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm		Boiling Point: °C	
Sample Wt 20 mg		Refractive Index, n ^D ₂₀	
Picatinny Arsenal Apparatus, in.	16	n ^D ₂₅	
Sample Wit, mg	21	n ₃₀	
Friction Pendulum Test: (b)		Vacuum Stability Test	(a b)
Steel Shoe	Unaffected	cc/40 Hrs, at	(2, 0)
Fiber Shoe		90°C	
	<i>.</i>	100°C	0.47
Rifle Bullet Impact Test: Trials	(b)	120°C	0.98
Evolutions 73		135°C	
Partials		150°C	11+
Burned		200 Come Barel Sand Tasts	
Lipeffected 28		Sand am	48.1
			10.1
Explosion Temperature: °C Seconds, 0.1 (no cap used)	(a)	Sensitivity to Initiation: Minimum Detonating Charge, gm	
1		Mercury Fulminate	
5 480		Lead Azide	0.20
10		Tetryl	0.10
15			
20		Ballistic Mortar, % TNT: (d)	133
75°C International Heat Tests		Trauzi Test, % TNT:	
% Loss in 48 Hrs		Plate Dent Test: Method	
100°C Heat Test:	(b)	Condition	
% Loss 1st 48 Hrs	0.058	Confined	
% Loss 2nd 48 Hrs	0.00	Density, gm/cc	
Explosion in 100 Hrs	None	Brisance, % TNT	
		Detonation Rate:	(a. b)
Flammability Index:		Confinement	None
		Condition	Cast
Hygroscopicity: % 30°C, 95% RH, 7	days 2.98	Charge Diameter, in.	1.0
71°C, 95% RH, 7	days 1.13	Density, gm/cc	1.69
Volatility:		Rate, meters/second	7224
			,

Booster Sensitivity Test: Condition	(c) Cast	Decomposition Equation: Oxygen, atoms/sec	
Tetryl, gm	100	(Z/sec)	
Wax, in. for 50% Detonation	1.25	(AH kcal/mol)	
Wax am		Temperature Range, °C	
Density om/cc	1.73	Phase	
Density, gin/ cc	2.15	Literat framewise	
Heat of:	(b)	Armor Plate Impact Test:	04
Combustion, cal/gm	3882		
Explosion, cal/gm	919	60 mm Mortar Projectile:	
Gas Volume, cc/gm		50% Inert, Velocity, ft/sec	
Formation, cal/gm	758	Aluminum Fineness	
Fusion, cal/gm 78°C	9.25	di AW si	
		500-lb General Purpose Bombs:	
Specific Heat: cal/gm/°C	(b)	Attemptor to ret	
30°C	0.249	Plate Thickness, inches	
50 ⁰ C	0.264	art traided a	
	0.204	11/4	
		114 part of options	
		13/	
Runing Patos			
cm/sec			
		Bomb Drop Test:	
Thermal Conductivity: cal/sec/cm/°C 35 [°] C	(b) 0.97 x 10 ⁻³	T7, 2000-Ib Semi-Armor-Piercing Bomb vs C	Concrete:
0 /// 1 / F	(Ъ)	Max Safe Drop, ft	
Linear Alanch		FOO IL Concert Burners Berth ve Concertor	
0°C	46 x 10 ⁻⁴	500-16 General Purpose bomb vs Concrete:	
35°C	95 x 10	Height, ft	
70°C	T2A X T0 ,	Triols	
Hardness, Mohs' Scale:		Unoffected	
Young's Modulus:	(b)	High Order	
E', dynes/cm ²	10.3 x 10 ⁷ _	Figh Order Baland	
E, Ib/inch ²	1.49 x 10 ⁻⁵	1000-lb General Purpose Bomb vs Concrete:	
Density, gm/cc	1.69	No. of the second s	
		– Height, ft	
Compressive Strength: Ib/inch ²	See below	Trials	
		Unaffected	
Vapor Pressure:		Low Order	
°C mm Mercury	(5)	High Order	
Compressive Strength: 1b/inch ²	1303		
Density, gm/cc	1.69		
	1 28		

HBX-1

Fragmentation Test: (b)	Shaped Charge Effectiveness, TNT $=$ 100:			
90 mm HE, M71 Projectile, Lot EGS-1-17: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Hole Volume Hole Depth	Cones		
Total No. of Fragments: For Composition B 998	Color:	Gray		
For Subject HE 910 For 80/20 Tritonal 616	Principal Uses:	HE charge		
3 inch HE, M42A1 Projectile, Lot KC-5:	1			
Density, gm/cc				
Charge Wt, Ib				
Total No. of Fragments: For TNT	Method of Loading:	Cast		
For Subject HE	Loading Density: gm/cc	1.69		
Fragment Velocity: ft/sec At 9 ft At 25½ ft				
Density, gm/cc	Method	Dry jacks		
Blast (Relative to TNT); (a)	– Hazard Class (Quantity-Distance)	Class 9		
Air: 3.25" diameter sphere Peak Pressure △ psi Catenary 24.7 NFOC Pendulum 19.6	Compatibility Group Exudation	Group I None		
Energy	1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1			
Air, Confined: Impulse		n		
Under Water: Peak Pressure				
Impulse Energy		in the second		
Underground: Peak Pressure	da an airtin ing	en e		
Impulse				
Energy		Parate Personal I		
	s i retere			
		an a		

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Composition:	a standard and a standard	Molecular Weight:	64
% צרוא צרוא	an original	Oxygen Balance:	1011-02
INT 29	Construction 201	CO ₂ %	-75
Aluminum 35	have a straight of		-49
D-2 Wax 5	11 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1	Density: gm/cc Cast	1.84
Calcium Chloride, added 0.5		Melting Point: °C	
C/H Ratio	a partiti approxi-	Freezing Point: °C	and all a
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	hald on the BW	Boiling Point: °C	n angganan k
Sample Wt 20 mg		Refractive Index, n ^D ₂₀	
Picatinny Arsenal Apparatus, in. 15		n ₂₅	
Sample Wt, mg 23	and the second	n ₃₀	
Friction Pendulum Test:	and some in the	Vacuum Stability Test:	(a, b)
Steel Shoe Una	affected	cc/40 Hrs, at	
Fiber Shoe		90°C	
)	100°C	0.45
Rifle Bullet Impact Test: Trials (b))	120°C	
Fundacions 78	.8	135°C	
Explosions [0		150°C	
Purnad	- 1946,	200 Come Bowl Sand Tast	(2)
Lipoffected 22	an dend south	Sand am	44.9
Explosion Temperature: °C (a) Seconds, 0.1 (no cap used) 1 5 500 10) ar - Josén an José (688	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	0.20 0.10
15		(z)	and the stand of the
20		Ballistic Mortar, % TNT: (d)	111
	RAD IN	Trauzl Test, % TNT:	an dela mandata banda manadata dati
75°C International Heat Test: % Loss in 48 Hrs		Plate Dent Test: Method	
100°C Heat Test: (b)		Condition	
% Loss let 48 Hrs	70	Confined	
% Loss 2nd 48 Hrs 0.	20	Density, gm/cc	
Evolution in 100 Hrs		Brisance, % TNT	
Flammability Index:		Detonation Rate: Confinement	(a, b) None
2000 050 20 7 400	ure 2.01	Condition	Cast
Hygroscopicity: % 30°C, 95% RH, 7 day (b) 71°C, 95% RH, 7 day	vs 0.31	Charge Diameter, in.	1.0
	,,,-	Density, gm/cc	1.81
Volatility:		Rate, meters/second	6917



Booster Sensitivity Test: Condition	Mielseven Wilder	Decomposition Equation: Oxygen, atoms/sec	Translation and D
Tetryl, am		(Z/sec)	
Wax in for 50% Detonation		Heat, kilocalorie/mole	
Wax, m. for 50 % Detonation		(ΔH, kcal/mol)	
wdx, gm		Temperature Range, °C	
Density, gm/cc	Etallong Rein S.	Phase	
Heat of: Combustion, cal/gm	(b) 4495	Armor Plate Impact Test:	C.44 Katin
Explosion, cal/gm	877	60 mm Martas Projectiles	
Gas Volume, cc/gm		50% Inert. Velocity, ft/sec	man the first the average of
Formation, cal/am	491	Aluminum Fineness	and the statement
Fusion cal/am	9.30	Alamian Theress	
		500-lb General Purpose Bomb	S:
Specific Heat: cal/gm/°C		and a state of the second	
30 ⁰ C	0.254	Plate Thickness, inches	
5	16-14-04-05	field the "Fit was,"	
50°C	0.254	1	
		11/4	
		11/2	
	100	134	
Burning Rate:		2007 -	
cm/sec		Bomh Drop Test:	in and in the second
P P P P P P P_	1.)	Domb Drop Test.	
cal/sec/cm/°C 35°C	(b) 1.70 x 10 ⁻³	T7, 2000-Ib Semi-Armor-Piero	ing Bomb vs Concrete:
C (() + (E	(2)	Max Safe Drop, ft	
Linear ΔL /inch			•
0°C	40×10^{-4}	500-16 General Purpose Bom	vs Concrete:
35°C	83 x 10^{-4}_{-1}	Waisht (t	
70 ⁰ C	130×10^{-4}		
Hardness, Mohs' Scale:	an 9. Loo and Restriction	Irials	
	Transi Tau, & THT:	Unaffected	
Young's Modulus:	(b)	Low Order	
E' dynes/cm ²	11.5×10^9	High Order	
$E_{\rm J}$ b/inch ²	1.67×10^5		
Density am/cc	1.81	1000-Ib General Purpose Bom	b vs Concrete:
Denarty, ghi/ ce	1.01	Height ft	
Compressive Strength Ib/inch2	See helow		
compressive strength, ib/ men	Dee Detow	Trials	
	TATE I SAMATING ME	Unaffected	
Vapor Pressure:	Comparing the second	Low Order	
°C mm Mercury		High Order	
Compressive Strength: 1b/inc	h ² 1610		
Density, gm/cc	1.81	11	2
Ultimate deformation, %	1.37		
	Pate, menu unite alteration		

Fragmentation Test:			Shaped Charge Effectiveness, $TNT = 100$:		
90 mm HE, M71 Projectile, L Density, gm/cc	.ot EGS-1-1	7:	Glass Cones Steel Cones Hole Volume		
Charge Wt, Ib			Hole Depth		
Total No. of Fragments: For Composition B		998	Color:	Gray	
For Subject HE For 80/20 Tritonal		476 616	Principal Uses:	HE charge	
3 inch HE, M42A1 Projectile, Density, gm/cc	, Lot KC-5:		and the second s		
Charge Wt, ID				man gang harde	
Total No. of Fragments: For TNT			Method of Loading:	Cast	
For Subject HE			Loading Density: gm/cc	1.81	
Fragment Velocity: ft/sec At 9 ft At 251/6 ft		后并 - 中 (¹ - 中	Storage:	nervini da Albara	
Density, gm/cc			Method	Dry	
Blast (Relative to TNT):		(a)	- Hazard Class (Quantity	y-Distance) Class 9	
Air: 3.25" diameter sph Peak Pressure ∆ psi Cat	tenary	25.5	Compatibility Group	Group I	
Impulse NFOC Pe Energy	endulum		Exudation	None	
Air, Confined: Impulse			Spinie Spinie		
Under Water: Peak Pressure					
Impulse Energy			- 1980-10 - 2011.0		
Underground: Peak Pressure Impulse Energy			antin adam of 100° at 10 µtana - Minter train again		

Without Desiccants and Containing Added Moisture							
parte and a second s	Moisture,	Acidity,	100°C Vac	Stab Test	Hygroscopicity, % 95% RH		
Explosive	26	20	cc gas	Hours			
Composition					30°C	71 ⁰ C	
Standard HBX-1 +0.2% moisture	0.73	0.011	0.47 0.68	40 40	+2.98	+1.13	
+0.4% moisture +0.6% moisture	-		0.62 0.50	40 40	n de service S		
HBX-1 without CaCl2 +0.2% moisture	0.00	0.029	0.36 0.25	40 40	-0.06	-0.25	
+0.4% moisture +0.6% moisture	-		0.23 0.27	40 40	4 d.		
HBX-1 with silica gel	0.06	0.031	0.73	40	+0.08	+0.04	
Standard HBX-3 +0.2% moisture	0.54	0.012	0.45	140 140	+2.01	+0.31	
+0.4% moisture +0.6% moisture			0.43	40			
HBX-3 without CaCl ₂ +0.2% moisture +0.4% moisture +0.6% moisture	0.02	0.049	0.46 0.26 0.26 0.20	40 40 40 40	-0.06	-0.29	
HBX-3 with silica gel	0.04	0.100	0.45	40	+0.09	+0.05	
Standard H-6 +0.2% moisture	0.71	0.017	0.47 0.88	40 40	+2.01	+1.77	
+0.4% moisture +0.6% moisture			0.63 0.65	40 40			
H-6 without CaCl +0.2% moisture +0.4% moisture +0.6% moisture	0.03	0.082	0.40 0.10 0.25 0.23	40 40 40 40	-0.06	-0.25	
H-6 with silica gel	0.05	0.028	0.43	40	+0.09	+0.06	

* All samples were ground to 20/100 mesh size, 7 days before tests. Silica gel used was Fisher Scientific Company, Lot 541492, through 100 mesh U. S. Standard Sieve.

HBX-1; HBX-3

Preparation:

HEX explosive mixtures are prepared by melting TNT in a steam-jacketed melt kettle equipped with a mechanical stirrer. Water-wet RDX is added slowly with stirring and heating until all the water is evaporated. Aluminum is added, and the composition is stirred until uniform. D-2 wax and calcium chloride are then added. The desensitizer wax, also known as Composition D-2, consists of 84% paraffin and other waxes, 14% nitrocellulose and 2% lecithin. The mixture is cooled from approximately 95° to 100° C to a temperature considered suitable for casting (the lowest practicable pour temperature). HEX can also be made by adding the calculated amount of TNT to Composition B to obtain the desired proportion of RDX/TNT. The appropriate weights of the other ingredients are added to complete the mixture.

Origin:

Developed during World War II, as relatively insensitive mixtures, by adding 5% desensitizer to Torpex II, for high blast explosive applications.

References: 34

(a) O. E. Sheffield, Blast Properties of Explosives Containing Aluminum or Other Metal Additives, PATR No. 2353, November 1956.

(b) S. D. Stein, G. J. Horvat and O. E. Sheffield, Some Properties and Characteristics of HBX-1, HBX-3 and H-6, PATR No. 2431, June 1957.

(c) L. C. Smith and S. R. Walton, <u>A Consideration of RDX/Wax Mixtures as a Substitute for</u> Tetryl in Boosters, NOL Memo. 10,303, <u>15 June 1949</u>.

(d) S. R. Walton, Report on the Program to Develop an Improved HBX-Type Explosive, NAVORD Report No. 1502, 26 July 1950.

(e) A. W. O'Brien, Jr., C. W. Plummer, R. P. Woodburn and V. Philipchuk, <u>Detonation</u> <u>Velocity Determinations and Fragment Velocity Determinations of Varied Explosive Systems</u> <u>and Conditions</u>, National Northern Corporation Final Summary Report NNC-F-13, February 1958 (Contract DAI-19-020-501-ORD-(P)-58).

(f) Also see the following Picatinny Arsenal Technical Reports on HBX Explosives: 1756, 2138, 2169.

HEX-24

Composition:		Molecular Weight:	47.6
70 Potassium Perchlorate (17 microns) Aluminum, atomized	32 48	Oxygen Balance; CO ₂ % CO %	-42 -34
RDX (through 325 mesh)	16),	Density: gm/cc Apparent Pressed at 20,000 psi	1.39 2.1
Asphartam (dirough 100 mesh)	4 100 10 10 10 10 10 10 10 10 10 10 10 10	Melting Point: °C	a album (a c.) Album (album (
C/H Ratio		Freezing Point: °C	te in nedition. Les annesites
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C	
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg		Refractive Index, n ^D ₂₀ n ^D ₂₅	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Detonates Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C	49,1 0,494
Rifle Bullet Impact Test: Trials		100°C 120°C	1.25
% Explosions Partials		135°C 150°C	
Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm	12.5
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 520 10	Ta in sti hinner Da in sti hinner Dan Vinine Da i National Sabistan	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	0.20 0.25
20		Ballistic Mortar, % TNT:	
		Trauzl Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs		Plate Dent Test: Method	
100°C Heat Test:		Condition	
% Loss, 1st 48 Hrs	0.15	Contined	
% Loss, 2nd 48 Hrs	0.00	Brisance % TNT	
Explosion in 100 Hrs	None		
Flammability Index:		Detonation Rate: Confinement	
Hygroscopicity: %	None	Condition Charge Diameter, in.	
Volatility:	None	Density, gm/cc Rate, meters/second	

Fragmentation Test:	Shaped Charge Effectiveness, $TNT = 100$:			
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Cones Hole Volume Hole Depth			
Total No. of Fragments: For TNT	Color: Gray			
For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib	Principal Uses: HE filler for small caliber projectiles			
Total No. of Fragments: For TNT For Subject HE	Method of Loading: Pressed			
Fragment Velocity: ft/sec	Loading Density: gm/cc Pressed at 20,000 psi 2.1			
At 25½ ft Density, gm/cc	Storage: Method Dry			
Blast (Relative to TNT):	Hazard Class (Quantity-Distance)			
Air: Peak Pressure Impulse Epergy	Compatibility Group Exudation None			
Air, Confined: Impulse	Static Tests: <u>20 mm T215El Projectile:</u> PA Peak Pressure, psi 55 NFOC 20" Blast Cube 44 APC Ob" Plast Cube 44			
Under Water: Peak Pressure Impulse	Static Tests: 20 mm M97 Projectile:			
Energy	Foxboro psi <u>HEX-24</u> <u>Tritonal</u> <u>Torpex</u> 19 12.4 13.0			
Underground: Peak Pressure Impulse	Catenary psi 46 Duration, microsec 533 APG 24" Blast Cube 36 24 32			
Energy	Heat of:			
Flame Temperature, OK2552Activation Energy, kcal20.4Temp, OC450 to 570Specific reaction1.64 x 10^{-5}	Combustion, cal/gm 4197 Explosion, cal/gm 1858 Gas volume, cc/gm 159			

AMCP 706-177

HEX-48

Composition: 001 111 (dekonercise) Fill opend() inspecti	Molecular Weight: 47.6				
Potassium Perchlorate 32 (17 microns) Aluminum, flaked (1 micron) 48	Oxygen Balance: CO ₂ % CO%	-42 -34 0.69 1.62			
RDX (through 325 mesh) 10 Asphaltum (through 100 mesh) 4	Density: gm/cc Apparent Pressed at 20,000 psi				
	Melting Point: °C	Tetta			
C/H Ratio	Freezing Point: °C	ali			
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	e al sa la c			
Sample Wt 20 mg	Refractive Index, n ^D ₂₀				
Picatinny Arsenal Apparatus, in. Sample Wt. ma	n ^D ₂₅				
	n ^D ₃₀	nt i sasif			
Friction Pendulum Test:	Vacuum Stability Test:				
Steel Shoe Partially detonates	cc/40 Hrs, at				
Fiber Shoe Unaffected	- 100°C	1.52			
Rifle Bullet Impact Test: Trials	120°C				
%	135°C				
Explosions	150°C				
Partials	200 Green Romb Sand Torts				
Linaffected	Sand, gm	23.7			
	Constativitari an Initiationi				
Explosion Temperature: °C	Minimum Detonating Charge, am				
	Mercury Fulminate				
5 545	Lead Azide	0.20			
10	Tetryl	0.25			
15	Ballistic Mortar, % TNT:	ACT (DA) Desci			
20					
75°C International Heat Test:	Plate Dent Test:	r minsid den ¹			
% Loss in 48 Hrs	Method				
100°C Heat Toth	Condition				
% Loss let 48 Hrs	Confined				
% Loss 2nd 48 Hrs	Density, gm/cc				
Explosion in 100 Hrs	Brisance, % TNT	- 0-8 ···			
	- Detonation Rate:				
Flammability Index:	Confinement				
	- Condition				
Hygroscopicity: %	Charge Diameter, in.				
Valatility	Density, gm/cc				
volutinty;	Rate, meters/second				

HEX-48

Fragmentation Test:	Shaped Charge Effectiveness, TNT $=$ 100:
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Cones Hole Volume Hole Depth
Total No. of Fragments: For TNT	Color: Gray
For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib	Principal Uses: HE filler for small caliber projectiles
Total No. of Fragments: For TNT For Subject HE	Method of Loading: Pressed
Fragment Velocity: ft/sec At 9 ft At 251/2 ft	Loading Density: gm/cc Pressed at 20,000 psi 1.62 Storage:
Density, gm/cc	Method Dry
Blast (Relative to TNT): Air: Peak Pressure Impulse	Hazard Class (Quantity-Distance) Compatibility Group Exudation None
Energy Air, Confined: Impulse Under Water: Peak Pressure	Static Tests:20 mm T215E1 Projectile:PA Peak Pressure, psi77NFOC 20" Blast Cube45APG 24" Blast Cube42Static Tests:
Impulse Energy Underground: Peak Pressure	20 mm M97 Projectile:HEX-48TNTTetrylFosboro psi17.32.83.5Catenary psi432828Duration, microsec517560530APG 24" Blast Cube2910
Impulse Energy Flame Temperature, ^O K 2382 Activation Energy, kcal 25.4 Temp, ^O C 450 to 470 Specific reaction rate, k 7.84 x 10 ⁻⁶	Heat of: Combustion, cal/gm 4119 Explosion, cal/gm 1735 Gas Volume, cc/gm 200

HEX-48

Cook-Off Tests: (c)

20 mm T215E1 HEX-48 Loaded Projectiles With Dye-Coated RDX Top-Off

Projectile No.	Cut-Off Temp. °C	Cook-Off
1	170 I70	Yes (198)
2	150	No
3	155	Yes (190)
<u>1</u>	150 to 175	No

National Northern Projectile Load:

MOX-2B (no top-off)	195
MOX-2B (Tetryl top-off)	150
MOX-2B (97/3, RDX/wax top-off)	175
MOX-2 (no top-off)	175

Fragment Penetration Tests: (c)

	, i pelunte		Avg. No. of Penetrations per Round in Zone 65°-130°		
Projectile	Filler	Altitude, Feet	0.020"	0.040"	0.051"
T215E1	HEX-48	Ground	352	264	282
		60,000	676	432	388
T282E1	MOX-2B	Ground	634	290	235
		60,000	807	367	250
EX8 Mod 0	MOX-2B	Ground	476	268	224
	and root like	60,000	672	264	256

The fragment penetration test records numbers of complete penetrations of aluminum panels of various thicknesses at 2.5 feet from the static detonation. The total penetrations recorded on the 24ST-3 aluminum panels occurred with the projectile nose always pointed toward C^{0} and the base toward 180° .

The test data indicate that on the thicker panels, 0.040" and 0.051," the HEX-48 loaded T215El projectile produced more complete fragment penetrations at ground and altitude than MOX-2B loaded T282El and EX8 Mod 0 projectiles.

Preparation:

The HEX compositions were prepared by blending the appropriate weight of the dry ingredients in a Patterson-Kelly twin-shell blender for at least 30 minutes.

An alternate procedure for 100 to 200 gram batches used a "Cradle-Roll" mixing device. This device consisted of a half-barrel type container constructed of wood and lined with an electrical conductive material. A plastic roll was allowed to move over the ingredients by remote control action of the container. The roll action prevented caking of the mix but had no adverse effect on the particle size of the ingredients. The period of time required to obtained a uniform and intimate mixture was approximately fifteen minutes.

Origin:

The development of "slow-burning" explosive mixtures which would produce increased blast effects in enclosed or nearly enclosed spaces directed attention to their use for possible military application. In 1950 Picatinny Arsenal developed a high capacity filler for 20mm projectiles consisting of 85/10/5 RDX/aluminum/desensitizer which was more powerful than standard tetryl filler. However, in comparison with MOX type explosives, there was little doubt as to the superior performance of the MOX mixture. HEX (high energy explosive) mixtures were developed at Picatinny Arsenal in 1953 (Ref a) as superior high blast compositions suitable for use in small caliber projectiles.

References: 35

(a) O. E. Sheffield and E. J. Murray, <u>Development of Explosives—Metallized Explosives</u> <u>High Blast Fillers for Small Caliber Shell</u>, <u>Picatinny Arsenal Memorandum Report No. MR-49</u>, 21 December 1953.

(b) O. E. Sheffield, <u>Properties of MOX-Type Explosive Mixtures</u>, PATR No. 2205, October 1955.

(c) National Northern Corporation, Letter from Dr. C. M. Saffer, Jr., to Commanding Officer, Picatinny Arsenal, 12 June 1957.

2,4,6,2',4',6'-Hexanitro-oxanilide (HNO)

Composition:	Molecular Weight: $(C_{14}H_6N_8O_{14})$	
% % C 33.0 C	Oxygen Balance: CO % CO %	-53.4 - 9.4
	Density: gm/cc	an a
$\begin{array}{c} \mathbf{N} \\ 21.9 \\ 0 \\ \mathbf{2N} \\ 1 \\ 1 \\ 1 \\ 0 \\ \mathbf{2N} \\ 1 \\ 1 \\ 1 \\ 0 \\ \mathbf{2N} \\ 1 \\ 1 \\ 1 \\ 0 \\ \mathbf{2N} \\ 1 \\ 1 \\ 1 \\ 0 \\ \mathbf{2N} \\ 1 \\ 1 \\ 1 \\ 0 \\ \mathbf{2N} \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ $	Melting Point: °C Decomposes	302
C/H Ratio 0.797 NO ₂ NO ₂	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	
Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 15 Sample Wt, mg 12	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	10 m m 11
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C	
Rifle Bullet Impact Test: Trials % Explosions Partials	120°C 135°C 150°C	
Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm	52.1
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 384	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide	 0.30
10	Tetryl	0.25
15	Ballistic Mortar, % TNT:	
20	Trauzi Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method	
100°C Heat Test: % Loss, 1st 48 Hrs 0.07 % Loss, 2nd 48 Hrs 0.05 Explosion in 100 Hrs None	Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:	- Detonation Rate: Confinement	
Hygroscopicity: % 25°C, 90% RH 0.19	- Condition Charge Diameter, in.	
Volatility:	Rate, meters/second	

Fragmentation Test:	Shaped Charge Effectiveness, TNT $=$ 100:			
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones Steel Cones			
Density, gm/cc	Hole Volume			
Charge Wt, Ib	Hole Depth			
Total No. of Fragments:	Color:			
For TNT				
For Subject HE	Principal Uses: Igniter powder; pyrotechnic			
3 inch HE, M42A1 Projectile, Lot KC-5:	compositions			
Density, gm/cc				
Charge Wt. Ib	the state of the s			
	<i>a</i>			
Total No. of Fragments:	Mathad of Loading: Pressed and artmudad			
For TNT	memod of Louding: riessed and extraded			
For Subject HE	nen) an each anns a'r annafail - 16, 18,418,112,123,123,121 Annaf			
	Loading Density: gm/cc			
Fragment Velocity: ft/sec	bid has not persient at shart by			
At 9 ft				
At 251/2 ft	Storage:			
Density, gm/cc	Method			
	Dry			
Blast (Relative to TNT):	Hazard Class (Quantity-Distance) Class 9			
Air	Compatibility Group			
Peak Pressure	company croup			
Impulse	Exudation None			
Energy	 M. D. Sont and M. Sont I. (1971) and S. Markellan and Constraints and Physical Sciences. 			
Air Confined.	serficient, e anna (1976, perte danest, 165			
Impulse	¹⁷ <u>A MAR IN ACT OF THE ACT </u>			
 A franklik and a status second statement 	the second second of the second se			
Under Water:	10.01: The second s			
Peak Pressure				
Impulse				
Energy				
Underground:				
Peak Pressure	(20) R. M.			
Impulse	All and the second of the second sec second second sec			
Energy				

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Solubility in the following substances:

Solvent				
Nitrobenzene Water	<3 gm in 100 cc, at 23°C ~ 5 gm 0.10 gm in 100 cc, at 100°C	n in 100) cc, at 210 ⁰ C	
Alcohol (Ethyl)	Insoluble			
Acetone	Insoluble			
Benzene	Insoluble			
Butyl acetate	Insoluble			
Carbon tetrachloride	Insoluble			
Dimethylformamide	Very soluble			
Ether (Ethyl)	Insoluble			
Acetic Acid	Insoluble			
Nitric Acid	Soluble			
Crystalline form	Long rectangular glistening plate	es from	nitrobenzene	

Preparation:

To prepare hexanitro-oxanilide, first prepare tetranitro-oxanilide as described herein under the entry "2,4,2',4'-Tetranitro-oxanilide (TNO)."

A 1.5 liter round bottom flask is equipped with a stirrer of the type which causes a downward swirl. The flask is jacketed for hot and cold water. 187 grams of nitric acid of specific gravity 1.49 (commercial grade) is placed into the flask and 100 grams of sulphuric acid is added to the nitric acid under agitation. The mixed acid is cooled to 10°C. 29.2 grams of tetranitro-oxanilide is slowly added to the mixed acid under rapid agitation maintaining the temperature at 8°-10°C. After the addition of the TNO is completed (approximately 25 minutes) the temperature is raised to 85°C over a period of 2 hours and held at 85°-90°C for one hour. The hexanitro-oxanilide (HNO) "slurry" is filtered on a Büchner funnel and purified as explained under "Tetranitro-oxanilide."

Origin:

A. G. Perkin in 1892 obtained hexanitro-oxanilide directly by heating to boiling a solution of tetranitro-oxanilide in a mixture of sulfuric and nitric acids. He also prepared the same compound from oxanilide by the action of a boiling mixture of fuming nitric and sulfuric acids (J Chem Soc 61, 462 (1892)).

References: 36

(a) L. Gowen and R. Dwiggens, <u>Case Gun Ignition Studies</u>, NAVORD Report No. 2321, 13 June 1952.

(b) D. Dubrow and J. Kristal, Substitution of Tetranitro Oxanilide and Hexanitro Oxanilide for Tetranitro Carbazole, PA Pyrotechnic Research Laboratory Report 54-IF1-88, 20 December 1954.

(c) S. Livingston, Preparation of Tetranitro Carbazole, PA Chemical Research Laboratory Report 136,330, 11 April 1951.

(d) S. Livingston, Development of Improved Ignition Type Powders, PATR No. 2267, July 1956.

³⁶See footnote 1, page 10.

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Composition:	Molecular Weight: (C1, HoNoOo) 296	
%		-
$C 16.2 O_2 N - N N - NO_2 I I I 2$	CO ₂ % -21.6	
н 2.7 н ₂ с сн ₂	CO % 0.0	
N 37.9 02 ^{N-N} N-N02	Density: gm/cc Crystal 1.90	
0 43.2 CH ₂	Melting Point: °C Capillary method 273 Koffer Micro Hot Stage 280	1
C/H Ratio 0.095	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	
Sample Wt 20 mg	Refractive Index, n ²	
Picatinny Arsenal Apparatus, in. 9		
Sumple W(, mg	nD	
Friction Pendulum Test		mil.
Steel Shoe	Vacuum Stability Test:	
Fiber Shoe Unaffected	cc/40 Hrs, at	
	- 100°C 0.37	
Rifle Bullet Impact Test: Trials	120°C 0.45	
~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~	135°C	
Explosions	150°C 0.62	tall.
Partials		_
Burned	200 Gram Bomb Sand Test:	
Unaffected	Sand, gm 60.4	
Explosion Temperature: °C	Sensitivity to Initiation:	
Seconds, 0.1 (no cap used) 380	Minimum Detonating Charge, gm	10
109-th through Process Frank vs. Consumed	Mercury Fulminate	
5 <u>327</u>	Lead Azide 0.30	
10 306	Tetryl	
20	Ballistic Mortar, % TNT: 150	121
	Trauzi Test, % TNT: 145	
75°C International Heat Test: Observation % Loss in 48 Hrs %	Plate Dent Test:	_
ification in the part in a second as	Condition	
UV C meat lest:	Confined	
% Loss, 1st 48 Hrs 0.05	Density am/cc	
% Loss, 2nd 48 Hrs 0.03	Brisance, % TNT	10
Explosion in IUU Hrs None prostand		
Flammability Index:	Detonation Rate:	14
	Condition	
Hygroscopicity: %	- Charge Diameter in	
30°C, 95% RH (c) 0.00	Density om/cc 1 Al	
Volatility:	Rote meters/second 01.04	
	Rate, meters/second 9124	

beta-HMX

Booster Sensitivity Test:	Melliondige Wilder	Decomposition Equation:	(e) 10 ¹ 9.7
Condition	United and a second	(Z/sec)	10
Tetryl, gm	ak _05	Heat, kilocalorie/mole	52.7
Wax, in. for 50% Detonation	- M - 0.2	(AH, kcal/mol)	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
Wax, gm		Temperature Range, °C	2/1-314
Density, gm/cc	a anna anna anna anna anna anna anna a	Phase	Liquid
Heat of:	2362	Armor Plate Impact Test:	
Employing and (and (a)	1356		
Explosion, cal/gm (C)		60 mm Mortar Projectile:	
Gas Volume, cc/gm	-60 5	50% inert, velocity, it/sec	
Formation, cal/gm (e)	-00.)	Aluminum Fineness	
Fusion, cal/gm		500-lb General Purpose Bombs:	
Specific Heat: cal/am/°C Recry	stallized (g)	NUMBER OF STREET	
°c <u>°c</u>		Plate Thickness, inches	
-75 0.153 85	0.288	1 V F	
0 0.228 90	0.290	1	
25 0.248 100	0.295	11/4	
75 0.282 150	0.315	11/2	
		13⁄4	
Burning Rate:			For Kernel La
cm/sec		Bomb Drop Test:	
Thermal Conductivity:		T7, 2000-Ib Semi-Armor-Piercir	g Bomb vs Concrete:
	Breediteire en house de		
Coefficient of Expansion:	Normal Revealed Street	Max Safe Drop, ft	
Linear, %/°C		500-lb General Purpose Bomb	vs Concrete:
Volume, %/°C		Height, ft	
		Trials	
Hardness, Mohs' Scale: (e)	2.3	Unaffected	
	THE R SHOT LEADER	Low Order	
Young's Modulus:		High Order	
E /b /inch ²			va Canarcha
Density, am/cc		1000-16 General Purpose Bomb	vs concrete:
	Çarhaq	Height, ft	
Compressive Strength: Ib/inch ²	Construction of the second	Trials	
and a second		Unaffected	
N D	the second state of the second state	Low Order	
°C mm Mercury		High Order	
			The second reaction
		for any and the second	

beta-HMX



Two men are required to regulate the addition of reagents and control the temperature during the initial stage addition; one man can complete the procedure. A l-liter 5-necked flask is used, the center neck for an efficient stirrer, one side neck for a thermometer, and the other necks for burrettes and a gas outlet (to water trap). The flask is placed in a pan with steam and cold water inlets, for temperature control.

Five cc of acetic anhydride and 250 cc glacial acetic acid are poured into the flask and the temperature brought to $45 \pm 1^{\circ}$ C, and held there for the duration of the entire reaction. The reagents (a solution of 33.6 gm hexamine in 55 gm of glacial acetic acid, 100 cc of acetic anhydride and 40 cc of a solution of 42.3/57.7-ammonium nitrate/98% nitric acid) are then added simultaneously, continuously and equivalently over a 25-minute period. The reaction

The second stage reagents (60 cc of 42.3/57.7, ammonium nitrate/98% nitric acid and 150 cc acetic anhydride) are then added simultaneously, continuously and equivalently over a 25-minute period. The mixture is aged 65 minutes, poured into 1.5 liter of water and simmered on a steam bath for 12 hours. Cool, filter and dry the RDX-HMX precipitate (yield 73% HMX).

The RDX is destroyed, leaving HMX, as follows: 1025 gm of the crude product are placed in a solution of 15 gm sodium tetraborate decahydrate in 5 liters of water, heated to boiling with agitation, and 5 N NaOH added at the rate of 3 cc/min. When about 730 cc have been added the pH increases sharply from a little over 8.7 to over 9.7 which corresponds to complete destruction of the RDX. Filter the HMX from the hot mixture; yield 612 gm, mp 279.5°-280.5°C. Recrystallization from nitromethane yields material melting at 281°-282°C.

Origin:

Was discovered as an impurity (by-product) in the nitration of hexamethylene-tetramine to form RDX. It is now manufactured directly by the process described above and has valuable use in explosive systems.

Removal of RDX from HMX-RDX Mixtures and Recovery of a RDX+HMX Mixture (This procedure appears suitable for use with mixtures containing 80% or more HMX):

Procedure:

500 grams of HMX containing 12.25% RDX are placed in a 1500 cc beaker, 500 cc of acetone is added and the slurry is agitated for several minutes at room temperature. Before complete settling, the RDX-HMX-acetone solution is decanted.

To the residual HMX-RDX, another 500 cc of acetone is added. The slurry is heated on the steambath and while boiling, agitated for several minutes. The boiling RDX-HMX-acetone solution is decanted. The residual HMX is now washed with cold acetone into a funnel. This HMX is now taken up in 95% alcohol, filtered and dried. Yield 353.9 gm or 70.78%.

All the acetone extracts are combined and evaporated to dryness. Yield 137.5 gm or 26.5%.

Yield Balance:

Pure HMX obtained - 353.9 gm	70.78%
Total RDX-HMX mixture recovered - 137.5 gm	26.50%
Samples taken during process - 2.4 gm Loss during process	0.48% 2.24%
Total	100.00%

Various samples were analyzed for RXD content:

1	Cruide	HMX	12.25% RDX
1.	After	finct acetone washing	6.0% RDX
2.	Arter	TIPSt account washing	2.0% RDX
3.	Aiter	second ace come washing	0.0% RDX
4.	After	third acetone washing	5) 50 PDY
RDX	-HMX sa	ample recovered	J4. J/ 10A

Preparation of Fine Particle-size HMX by the Aspirator Method:

1. Dissolve 1100 gm HMX in 4400 cc of dimethyl sulfoxide.

- 2. Filter the HMX solution.
- 3. Connect a clean aspirator to the water line.
- 4. Place a 55 gallon clean drum under the aspirator.
- 5. Fasten a polyethylene tubing, long enough to reach easily to the bottom of the HMXdimethyl sulfoxide container, to the side intake of the aspirator.
- 6. Fasten to the bottom of the aspirator another polyethylene tube long enough to reach to the bottom of the 55 gallon drum.
 - 7. Open the water faucet and then place the polyethylene tube in the HMX container.
 - 8. White milky fine HMX separates out in the drum. Total duration of run is approximately
 - 9. After all the HMX solution is sucked out of the container, the water is turned off.
 - 10. The material is filtered and water washed.
 - 11. If dry HMX is required, the material can be alcohol and ether washed.

A more efficient method to recover the RDX-HMX mixture:

- 1. Filter the combined hot acetone extracts.
- Pour while agitating the filtered extracts into at least 4 times its volume of water.
 Filter and dry, etc.

beta-HMX

Color:			
White			
Storage:			
Method		Dry	
Hazard	Class (Quantity-Distanc	e) Class 9	
Compat	ibility Group	Group L (dry) Group M (wet)	

Exudation

None

References: 37

(a) O. E. Sheffield, E. J. Murray, A. L. Rosen and B. W. Kanouse, Properties of HMX, PA Chemical Research Laboratory Report No. 52-IM1-23, 7 April 1952.

(b) W. E. Bachmann, The Preparation of HMX, OSRD Report No. 1981, 3 November 1943.

(c) S. Livingston, Characteristics of Explosives HMX and DPEHN, PATR No. 1561, 6 September 1945.

(d) R. J. Finkelstein and G. Gamow, <u>Theory of the Detonation Process</u>, NAVORD Report No. 90-46, 20 April 1947.

(e) O. H. Johnson, HMX as a Military Explosive, NAVORD Report No. 4371, 1 October 1956.

(f) Also see the following Picatinny Arsenal Technical Reports on HMX:

<u>1</u>	<u>3</u>	<u>6</u>	<u>7</u>	2
1741	2183	2016	1737	1709 2059

(g) C. Lenchitz, W. Beach and R. Valicky, Enthalpy Changes, Heat of Fusion and Specific Heat of Basic Explosives, PATR No. 2504, January 1959.

³⁷See footnote 1, page 10.

Composition:	Molecular Weight:	91
% 	Oxygen Balance:	Cap Edv
HMX 49	CO2 %	-51
INT 29	CO %	-27
Aluminum 22	Density: gm/cc Cast	1.90
	Melting Point: °C	
C/H Ratio	Freezing Point: °C	en nacional de la companya de la com
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	de ult
Bureau of Mines Apparatus, cm Sample Wt 20 mg	Refractive Index, no	
Picatinny Arsenal Apparatus, in. 17	5 ^D	
Sample Wt, mg 25	1125	
P. U. Phart - P	n ₃₀	
Friction Pendulum Test:	Vacuum Stability Test:	
Steel Shoe Unaffected	cc/40 Hrs, at	
Fiber Shoe Unaffected	90°C	a a 1750
D'fle Bullet langest Tests 30 Triple	100°C	
3/16" Steel 1/8" Al	120°C	0.37
Explosions 90 50	135°C	
Particla	150°C	
Particity 10	200 Gram Bamb Sand Tosti	
Burned 10	Sand am	61.3
Explosion Temperature:	Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)	Minimum Detonating Charge, gm	
1 8-04	Mercury Fulminate	
5 Flames erratically 370	Lead Azide	0.30
10	Tetryl	n an <u>a 199</u> Ta an Tao Nami
15	Ballistic Mortar, % TNT:	120
	Trauzi Test, % TNT:	
75°C International Heat Test:	Plate Dent Test:	
% Loss in 48 Hrs	Method	
	Condition	
IUU"C meat lest:	Confined	
% Loss, 1st 48 Hrs	Density, gm/cc	
% Loss, 2nd 48 Hrs	Brisance, % TNT	
Explosion in 100 Hrs		
Elemmability Index:	- Detonation Rate:	None
riammadility index.	Condition	Cast
Hyprocessicity: %		10
nygroscopicny. 70	Charge Diameter, in.	1.0
Volatility	Density, gm/cc	1.90
volutiny.	Rate, meters/second	1866

HTA-3

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc Heat of: Combustion, cal/gm Explosion, cal/gm Gas Volume, cc/gm Formation, cal/gm	3687 1190 680	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH, kcal/mol) Temperature Range, °C Phase Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness	 Pergeneration Life Pergeneration Life Pergeneration (Print Print) Pergeneration (Print Print) Pergeneration of Print Print Pergeneration (Print Print) Pergeneration (Print Print) Pergeneration (Print Print)
		500-lb General Purpose Bombs:	
Specific Heat: cal/gm/°C 32° to 74°C	0.245	Plate Thickness, inches	
i i i i i i i i i i i i i i i i i i i	Conding United	1 $1\frac{1}{4}$ $1\frac{1}{2}$ $1\frac{3}{4}$	
Burning Rate:			Participy and the
Thermal Conductivity: cal/sec/cm/°C	Hussie Cloud	T7, 2000-lb Semi-Armor-Piercir	ig Bomb vs Concrete:
Coefficient of Expansion: Linear, %/°C	rad nationed.	Max Safe Drop, ft 500-lb General Purpose Bomb	rs Concrete:
Volume, %/°C	adiat K ara tetra	Height, ft	
Hardness, Mohs' Scale:	(1) Suranut	Unaffected	
Young's Modulus: E', dynes/cm ²		Low Order High Order	
E, lb/inch ² Density, gm/cc		1000-Ib General Purpose Bomb	vs Concrete:
Compressive Strength: Ib/inch ²	2260 See below	Height, ft Trials Unaffected	
Vapor Pressure: °C mm Mercury <u>Compressive_Strength:</u> 1b/inch ²	*	Low Order High Order	
Average (10 tests) High Low	2260 2530 1910	Ultimate Deformation: % Average (10 tests) High Low	2.81 3.22 2.52

* Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

AMCP 706-177

HTA-3

Fragmentation Test:	Shaped Charge Effectiveness, TNT $=$ 100:	×.,
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones Steel Cones	
Density, gm/cc	Hole Volume	
Charge Wt, Ib	Hole Depth	
1.957	Dertify, gr	
Total No. of Fragments:	Color: Gray	. 7
For TNT	ally the Providence of the State of the	
For Subject HE	Principal Uses: HE projectile and bomb filler	
3 inch HE, M42A1 Projectile, Lot KC-5:		
Density, gm/cc	a second s	
Charge Wt, Ib	for a second	
1 (and fing) 1, 1 (1 (an ab)) 25 (32)	La des en la companya de la companya	
Total No. of Fragments:	Method of Loading: Cast	R.
For TNT		
For Subject HE		-
	Loading Density: gm/cc 1.90	
Fragment Velocity: ft/sec		
At 9 ft At 251/2 ft	Storage:	
Density, gm/cc	 The second s	1
the second s	Method Dry	
	- Hozard Class (Quantity-Distance) Class 9	
Blast (Relative to TNT):		
Air:	Compatibility Group Group I	-
Peak Pressure	in an interview of the second s	24
Impulse starts and constant property in the sub-disk free	Exudation None	
Energy		
Als Configurate	Work to Produce Rupture: ft-lb/inch ³ *	-
Impulse	Average (10 tests) 2.77] 4
	High 3.39	-
Under Water:	Low 2.40	Τ.
Peak Pressure	Efflux Viscosity, Saybolt Seconds: 24.8	
Energy	attaction of the second s	
Litergy	1 (eff.) (eff.) (eff.)	
Underground:		3
Peak Pressure	i i ca la	
Impulse	- A second second second second second second second second second second second second second second second second second second second se	
Energy	i i i i i i i i i i i i i i i i i i i	
	*Test specimen 1/2" x 1/2" cvlinder (approxi)	_
	mately 3 gm) pressed at 3 tons (6,000 lb)	
	total load or 30,000 psi with a 2 minute	
	orme or awerr.	
hand a provide state and a second state of the second state of the		

Modulus of Elasticity: *

	lb/inch ²	
Average	89,200	
High	97,400	
Low	76,300	

* Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

Setback Sensitivity Test: (a)

Critical Pressure	119,000 psi *
Density, gm/cc	1.92

* Pressure below which no initiation is obtained and above which an increasing percentage of initiations can be expected as the setback pressure increases.

Preparation:

Procedure similar to that used for Torpex.

References: 38

(a) 1st Indorsement from Chief, Explosives Development Section, to Chief, Explosives Research Section, Picatinny Arsenal, dated 12 May 1958. Subject: "Properties of Octols and HTA-3."

(b) R. Brown and R. Velicky, <u>Heat Capacity of HTA-3</u>, Picatinny Arsenal General Laboratory Report No. 58-H1-509, 5 May 1958.

Lead Azide

Composition:	Molecular Weight: (PbNg) 291
N 28.8 N=N=N-Pb-N=N=N	Oxygen Balance: CO ₂ % -5.5 CO % -5.5
Pb 71.2	Density: gm/cc Crystal 4.80 Dextrinated 4.38
	Melting Point: °C Decomposes
C/H Ratio	Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Pure Dextrinated Bureau of Mines Apparatus, cm 10 17	Boiling Point: °C
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3 5 Sample Wt, mg 30 28	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀
Friction Pendulum Test:	Vacuum Stability Test: Dextrinated
Steel Shoe Explodes Fiber Shoe Explodes	cc/40 Hrs, at 90°C 100°C 1.0
Rifle Bullet Impact Test: Trials	120°C 0.07
% Explosions	135°C
Partials	150°C
Burned	200 Gram Bomb Sand Test:
Unaffected	Sand gm Black powder fuse 19.0
Explosion Temperature: °C Seconds, 0.1 (no cap used) 396 1 356 5 Explodes 340 10 335	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl
20 335	Ballistic Mortar, % TNT:
	Trauzi Test, % TNT: (a) 39
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method
100°C Heat Test: % Loss, 1st 48 Hrs 0.34 % Loss, 2nd 48 Hrs 0.05 Explosion in 100 Hrs None	Condition Confined Density, gm/cc Brisance, % TNT
Flammability Index:	Detonation Rate: Pure Lead Azide Confinement
Hygroscopicity: % Dextrinated Not Dextrinated 30°C, 90% RH 0.8 0.03	Condition Pressed Charge Diameter, in. Density, gm/cc 2.0 3.0 4.0
v olarility:	Rate, meters/second 4070 4630 5180

Fragmentation Test:	Shaped Charge Effectiveness, $TNT=100$:				
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Cones Hole Volume Hole Depth				
Total No. of Fragments: For TNT	Color: White-buff				
For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib	Principal Uses: Detonators, priming compositions, and commercial blasting caps				
Total No. of Fragments: For TNT	Method of Loading: Pressed				
For Subject HE Fragment Velocity: ft/sec	Loading Density: gm/cc psi x 10 ³ 3 5 10 15 2.62 2.71 2.96 3.07				
At 9 ft At 25½ ft Density, gm/cc	Storage: Method Wet				
Blast (Relative to TNT):	Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group M (wet)				
Air: Peak Pressure	Exudation None				
Energy	A A A A A A A A A A A A A A A A A A A				
Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy	Compatibility with Metals: Dry lead azide does not react with or cor- rode steel, iron, nickel, aluminum, lead, zinc, copper, tin or cadmium. It does not affect coatings of acid-proof black paint, oil, NRC compound or shellac. Lead azide in the presence of moisture corrodes zinc and copper; and with copper, it forms the extreme- ly sensitive and dangerous copper azide.				
Underground: Peak Pressure Impulse Energy Heat of:	Specific Heat: cal/gm/°C °C -50 0 0 25 0.110				
Combustion, cal/gm 630 Explosion, cal/gm 367 Gas Volume, cc/gm 308 Formation, cal/gm -346	Thermal Conductivity: cal/sec/cm/°C (Pure) 1.55 x 10 ⁻⁴				

Compatibility with Metals:

<u>Dry:</u> Steel, iron, nickel, aluminum, lead, zinc, copper, tin, stainless steel, brass and bronze were unaffected by six years' contact with dry lead azide at ambient temperature and 50°C. Monel, chrome-nickel and Inconel were unaffected under the same conditions in two and one-half years.

Wet: Copper and zinc are rapidly attacked by moist lead azide, while aluminum is not attacked in 24 hours. Monel, chrome-nickel and Inconel are not attacked by lead azide $(\frac{1}{2}\%)$ moisture) after 29 months' exposure at ambient temperature and 50°C, and J-l magnesium-aluminum alloy is very slightly corroded.

		Lead Azide	Lead A	zide	Lead Azid plus 20%	e 2. Decke, di 1915 anismente di
Sample Tested	Dry Dry	25% Water	20% Wa	iter	hol (95%	$\overline{\Sigma}$
Friction Pendulum Tes	t:					
(All LA dextrinated)						
Shoe	Fiber	Fiber Stee	l Fiber	Steel	Fiber	
No. of Trials Explosions Cracklings Unaffected	l l O	10 12 0 0 0 2 10 10	10 0 0 10	4 2 1	1 1 0 0	
Impact Sensitivity, 2	Kg Wt:					
(All LA dextrinated)						
PA Apparatus, inch	es 4	9		9	4	
Activation Energy: (c)					
Kcal/mole Induction Period,	seconds	23.74 0.5-10				
Initiating Efficiency	, Grams Requ	uired to Give Com	plete Initiat	ions of:		
		Dextrinated Azi	de (gm)			
TNT Tetryl RDX PETN		0.25 0.10 0.05 0.02				
Sensitivity to Static	Discharge,	Joules (Pure Lea	<u>d Azide)</u> (b)		0.0070	

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Compatibility of Dextrinated Lead Azide with Black Powder: 100°C Vacuum Stability Test, cc/40 hr:

Sam	ple Wt ((gm)		Material	cc
	1.0			Lead Azide Black Dowder	0.50
	2.0			50/50, Lead Azide/Black Powder	1.26
Solubility	of Pure	Lead Azide;	gm/100	gm of Water:	

oC

20

%

0.05

Preparation of Lead Azide (Dextrinated): (du Pont procedure)

2 Na – N = N = N + Pb
$$(NO_3)_2 \rightarrow Pb(N_3)_2 + 2 NaNO_3$$

Lead nitrate solution: This is prepared by dissolving 164 lbs lead nitrate and 8.25 lbs dextrine in deionized water, the solution allowed to settle, and sodium hydroxide added to bring the solution to a pH of 5.4. The final concentration of the solution is then adjusted to 7.4% lead nitrate, 0.375% dextrine by addition of deionized water.

The lead azide is precipitated at a solution temperature of 160°F, using 60 parts lead nitrate and 50 parts sodium azide solution. The latter is added to the former in 23 minutes, under agitation (no baffles are used in the precipitation vessel), the mixture cooled to room temperature in 12 minutes, and allowed to settle 10 minutes. The mother liquor is decanted and the remaining slurry washed before packing.

Origin:

First prepared in 1891 by T. Curtius (Ber 24, 3345-6) by adding lead acetate to a solution of sodium or ammonium azide. F. Hyronimus (French Patent 384,792) should be credited with the first attempt in 1907 to use lead azide with some success in the explosive industry. Its commercial manufacture started in Europe before World War II and in the United States since 1931 as military or commercial grade "dextrinated" lead azide.

Destruction by Chemical Decomposition:

Lead azide can be decomposed by

(1) mixing with at least five times its weight of a 10% solution of sodium hydroxide and allowing the mixture to stand for 16 hours. Decant the supernatant solution of sodium azide and drain into the soil.

(2) dissolving in a 10% solution of ammonium acetate and adding a 10% solution of sodium or potassium bichromate until no more lead chromate is precipitated.

(3) wetting with 500 times its weight of water, slowly adding 12 times its weight of 25% sodium nitrite, stirring, and then adding 14 times its weight of 36% nitric or glacial acetic acid. A red color produced by the addition of ferric chloride solution indicates Lead Azide is still present.

Lead Azide

(4) dissolving in 50 times its weight of 15% ceric ammonium nitrate. The azide is decomposed with the evolution of nitrogen.

References: 39

(a) Ph. Naoum, Z ges Schiess Sprengstoffw, 181, 229, 267 (27 June 1932).

(b) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

(c) C. Lenchitz, <u>Ice Calorimeter Determination of Enthalpy and Specific Heat of Eleven</u> Organometallic Compounds, PATR #2224, November 1955.

(d) Also see the following Picatinny Arsenal Technical Reports on Lead Azide:

<u>o</u>	1	2	3	<u>4</u>	5	6	<u>7</u>	8	2
550 580 600 760 1450	561 861 1451 1651	832 852 932 1132 1152 1352 1372	393 1393 1493 2093 2133	534 784 824 944 2164 2204	255 525 1325 1485	326 856 1316 1486 1556	567 637 657 707 1737 2227	628 708 748 838 1388 1528 1838 2198	609 719 749 769 849 999 2179

10.112

ം ഇതുമെന്നുമായി പരിന്ന് നിന്നും നില്ലായില് (നിയന് ഇന് 2016) മിന്നും മോദാവില് വാനം പോയായിക്കിന്ന് നാന് വാനാവിക്ക ഇതുമില് മായ്പ്രംഗ്രായില് നിന്നും നിന്നും നിന്നും നിന്നും നിന്നും നിന്നും മോഗ്രം നിന്നും പ്രംഗ്രായിന്നും പ്രംഗ്ര ഇതുമില് തയോഗംഗംഗ്രാന് നിന്നും നിന്നും നിന്നും നിന്നും നിന്നും നിന്നും മോഗ്രം മെന്ന് നിന്നും പ്രംഗ്രായിന്നും മോഗ ഇതുമില് തലന്റെ നിന്നും നിന്നും നിന്നും നിന്നും നിന്നും നിന്നും നിന്നും മിന്നും പ്രംഗ്രംഗംഗ്രായില് മോഗ്രായില് മാ ഇതുമില് തലന്റെ നിന്നും നിന്നും നിന്നും പ്രംഗംഗംഗ്രാം നിന്നും നിന്നും പ്രംഗംഗംഗ്രംഗംഗംഗം മുള്ളം പ്രംഗംഗം മുള്ളം

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(a) the second and the second second second second second and a 1996 were related by any second approximation Mark Antibation (1986). It is a second second second state of the antipology of the ball and the ball and the s antibate #30% others, 1977, 1979.

fall stream and it. I have a set to the set of the second of the second set of the second set of the second set Besterman and set of the stream and the second set of the second set to second set of the second set of the

(1) Setting a Start of a setting of an a time and off all setting a superior of time of these black has a label.
(a) Setting a start of the set of a set of the and off of times the setting of the setting of the set of the

39See footnote 1, page 10.

Lead 2,4-Dinitroresorcinate (LDNR)

AMCP 706-177

Composition:	Molecular Weight: (PbC ₆ H ₂ N ₂ O ₆) 405
$ \begin{array}{cccc} C & 17.8 \\ H & 0.5 \\ N & 6.9 \end{array} $ $ \begin{array}{ccccc} 0 & - \\ N & 0_{2} \end{array} $	Oxygen Balance: CO ₂ % -32 CO % - 8
0 23.7 Pb 51.1	Density: gm/cc Crystal 3.2
Colors - real - real	Melting Point: °C
C/H Ratio 0.549	Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus cm 1 kg wt 30	Boiling Point: °C
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg 20	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀
Friction Pendulum Test:	Vacuum Stability Test:
Steel Shoe	cc/40 Hrs, at
Fiber Shoe	- 100°C
Rifle Bullet Impact Test: Trials	120°C (73 minutes) Explodes
% Explosions	135°C
Partials	150°C
Burned	200 Gram Bomb Sand Test:
Unaffected	Sand gm Black powder fuse 20
Explosion Temperature: °C. and Mitodiagonad	Sensitivity to Initiation:
Seconds, 0.1 (no cap used)	Minimum Detonating Charge, gm
5 Explodes 265	Mercury Fulminate
10	Tetryl
15	
20	Ballistic Mortar, % TNT:
131. fm/l	_ Trauzl Test, % TNT:
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method
100°C Heat Test:	Condition
% Loss, 1st 48 Hrs 0.20	Confined
% Loss, 2nd 48 Hrs 0.02	Density, gm/cc
Explosion in 100 Hrs None	Brisance, % TNT
Flammability Index:	- Detonation Rate: market Confinement
Hygroscopicity: % 30°C, 90% RH 0.73	– Condition Charge Diameter, in.
Volatility:	 Density, gm/cc Rate, meters/second

AMCP 706-177

Lead 2,4-Dinitroresorcinate (LDNR)

Fragmentation Test:	Shaped Charge Effectiveness, TNT $=$ 100:
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc	Glass Cones Steel Cones Hole Volume
Charge Wt, Ib	Hole Depth
Total No. of Fragments: For TNT	Color: Red or yellow
For Subject HE	Principal Uses: Electric detonators
3 inch HE, M42A1 Projectile, Lot KC-5:	the second second of the second se
Density, gm/cc	
Charge Wt, Ib	and the the second s
Total No. of Fragments:	Method of Londing:
For TNT For Subject HE	(me and filesed in Louing.
	Loading Density: gm/cc
Fragment Velocity: ft/sec At 9 ft At 25½ ft	Storage:
Density, gm/cc	Method Wet
Blast (Relative to TNT):	Hazard Class (Quantity-Distance) Class 9
Air: Peak Pressure	Compatibility Group
Impulse	Exudation None
Energy	
Air, Confined: Impulse	Initiating Efficiency: 0.4 gm LDNR does not initiate tetryl pressed at 3000 psi.
Under Water	Heat of:
Peak Pressure	Evalosion cal/am 270
Impulse	
Energy	
Underground: Deck Pressure	
	waters to the second
Fnerov	
	a star i staria a sentiti
	entering of the second s
	restance in the second s

Preparation:



To a solution of 5 grams of purified dinitroresorcin and 2.65 grams of anhydrous sodium carbonate in 500 cc of boiling water is added slowly a solution of 10 grams of lead nitrate dissolved in 60 cc of boiling water. The reaction mixture is constantly stirred during the addition of the lead salt and for about an hour afterward while the solution is allowed to cool to room temperature. The precipitate is filtered and washed thoroughly first with water and then with alcohol and ether. It is dried in a steam oven.

Origin:

2,4-dinitroresorcin was described in the 1881 edition of Beilstein (Beil VII, 885). The same compound was described in more detail by Weselsky, Benedikt and Hübl in 1882 (M II, 323). The lead salt of 2,4-dinitroresorcinol appears to have been prepared between World War I and World War II by treating resorcinol with nitrous acid and oxidizing the resulting dinitrosoresorcinol to dinitroresorcinol. Lead nitrate solution was then added to a solution of the 2,4-dinitroresorcinol to which sodium carbonate had been added to form the soluble sodium salt (J. D. Hopper, PATR No. 480, March 1934). The LDNR exists in two forms differing in physical characteristics but possessing similar explosive properties. These forms are red and orange in color (K. S. Warren, PATR 1448, September 1944).

References: 40

-Dinitroresorcinate:	on Lead 2,4	nical Reports	Arsenal Tec	Picatinny	See the following	(a)
	<u>9</u>	8	<u>4</u>	3	<u>o</u>	
	859 1079	1328 1448	1004	453	480 580	

⁴⁰See footnote 1, page 10.
Composition;	Molecular Weight: (Pb2C6H4N208) 646
$\begin{array}{cccc} & & & & & & \\ C & & & & & \\ H & & 0.6 & & \\ N & & 4.3 & & 2^N \end{array} $	Oxygen Balance: -20 CO ₂ % -20 CO % -5
Pb 64.1	
C/H Batio 0.177	Freezing Point: °C
Impact Sensitivity, 2 Ka Wt:	Boiling Point: °C
Bureau of Mines Apparatus, cm 1 kg wt 60 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg 20	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C
Rifle Bullet Impact Test: Trials % Explosions Partials	- 100°C 120°C 135°C 150°C
Burned Unaffected	200 Gram Bomb Sand Test: Sand 19m Black powder fuse 15
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Explodes 295 10 15	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl
20	Ballistic Mortar, % TNT:
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method
100°C Heat Test: 0.4 % Loss, 1st 48 Hrs 0.0 % Loss, 2nd 48 Hrs 0.0 Explosion in 100 Hrs None	Condition Confined Density, gm/cc Brisance, % TNT
Flammability Index:	Detonation Rate: Confinement
Hygroscopicity: %	Condition Charge Diameter, in.
Volatility:	Density, gm/cc Rate, meters/second

Lead 4,6-Dinitroresorcinol Basic (LDNR Basic)

AMCP 706-177

agmentation Test:	Shaped Charge Effectiveness, TNT	_ 100:
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones Ste	el Cones
Density, gm/cc	Hole Volume	
Charge Wt, Ib	Hole Depth	
Total No. of Fragments:	Color: R	ed or yellow
For TNT		
For Subject HE	Principal Uses: Elec	tric detonators
3 inch HE, M42A1 Projectile, Lot KC-5:		
Density, gm/cc	al de la suite a suite a suite de la suite	
Charge Wt, Ib	what is a second s	the trem of the ba
Total No. of Fragments:	Method of Loading:	Pressed
For TNT		
For Subject HE	Loading Density: gm/cc	A PRODUCT OF THE PARTY
reament Velocity: ft/sec	20010 and the unit with the sol from	or benevit be the set
At 9 ft	Storage:	stran i oberje
	en las de rennement dans d'art de las de	
Density, gm/cc	Method	Wet
last (Relative to TNT):	Hazard Class (Quantity-Distance	e) Class 9
and as an every section in (marrin 12-7)	Compatibility Group	
Peak Pressure	and the second statement of the second s	Dieve
Impulse	Exudation	None
Energy	A.A. and the second balance of the	
(a) It is significant, which is a property of the property	Initiating Efficiency: 0.4	gm LDNR Basic
Air, Contined:	does not initiate tetryl	pressed at 3000
 Market and the product of the second sec second second sec	psi.	
Under Water: Peak Pressure	ndenlar aldednik (d. 19 berrande sideo-	
Impulse		
Energy	and example make address after the debut	
Underground:	ne ja saa maagaan waxaya ahaa ka	
Peak Pressure	ten Millen in fan ster wer in de fin in de	
Impulse	n (1963), and an	
Energy	ney humberships to accounty in Verenth	
	[10] A. G. Land, A. M. Barris, M. M. M. Mark, "And M.	
	in the state the second the broads such ad	





(a) One hundred grams of pure resorcin is fused in a porcelain casserole and immediately poured on a glass plate. After cooling, the cake is ground in a mortar to pass a U. S. Standard No. 6 mesh screen. Four hundred grams of 98 percent nitric acid in a one pint capacity Dewar jar is stirred mechanically while carbon dioxide snow is added in small pieces. When the temperature falls to -20°C, 40 grams of the granulated resorcin is added in small quantities. Simultaneous addition of solid carbon dioxide as required prevents a rise of temperature of more than 5 degrees throughout the entire experiment. Five minutes after the last portion of resorcin is introduced, the mixture is further cooled to minus 50°C, and finally drowned with vigorous stirring in five times its volume of cracked ice, in water. This mixture is allowed to stand for one hour and the product then filtered, washed, and partially dried, weight 43.6 grams. The crude 4,6-DNR is purified by first dissolving the product in an aqueous 5 percent sodium hydroxide solution (17.4 grams of sodium hydroxide in 340 cc of water). The resulting solution is then neutralized by gradually adding it to a boiling solution of 21.4 grams of 98 percent sulphuric acid in 150 cc of water. The resulting precipitate of 4,6-DNR is filtered hot on a suction filter and air-dried. Yield, 27.5 grams (37.8 percent of the theoretical).

(b) Five hundredths (0.05) mole (18.96 grams) of lead acetate is dissolved in 67 cc of warm water, into which is gradually stirred 0.10 mole (4.0 grams) of sodium hydroxide dissolved in 67 cc of water. Stirring is continued for five minutes. After settling, the white lead hydroxide is washed by decantation three times with 100 cc portions of distilled water, and used immediately for the next operation.

(c) A 0.0278 mole (5.56 grams) quantity of the 4,6-DNR prepared under (a) above, is dispersed in 270 cc of water by vigorously beating with a motor stirrer. After heating this dispersion to 90°C, the 0.05 mole of lead hydroxide prepared above in slurry form is introduced in small portions. Agitation is continued for three hours at 90°C. The basic lead 4,6-DNR is washed once by decantation, and again on the filter with alcohol. After drying overnight in a desiccator charged with calcium chloride, the product weighs 15.6 grams.

Origin:

Both the 2,4- and 4,6-dinitroresorcin were described in some detail by Weselsky, Benedikt and Hübl in 1882 (M II, 323). Typke prepared the 4,6-dinitroresorcin in 1883 by hydrolyzing the nitration product of resorcin diacetate (Ber <u>16</u>, 551). A more direct and economical method of preparation suitable for production scale manufacture was developed during World War II by the British (Ministry of Supply Pouch Item W-154-21a, "Manufacture of 4,6-Dinitroresorcin and Lead 4,6-Dinitroresorcinate"). This procedure consisted of preparing 4,6dinitroresorcinol by direct nitration of granulated resorcin and allowing the product in slurry to react with an excess of lead hydroxide at 90° C. This basic salt can be prepared in two forms: (1) a micro-crystalline, yellow, low-density form and (2) a denser, brick-red form. Both products have the same chemical composition and the same sensitivity to impact (PATR 1448, September 1944).

Composition:	Molecular Weight: (PbC ₆ H ₃ N ₃ 0 ₉) 468
$ \begin{array}{c c} & 15.4 \\ H & 0.6 \\ N & 9.0 \end{array} \begin{array}{c} & 0 \\ 0_2 N \\ \hline & & N 0_2 \end{array} \\ PbH_0 0 \end{array} $	Oxygen Balance: CO2 % -19 CO % 2
0 30.8 Pb 44.2	Density: gm/cc Crystal 3.02
NO.	Melting Point: °C Explodes 260-310
C/H Ratio 0.320	Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 17	Boiling Point: °C
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3; (8 oz wt) 8 Sample Wt, mg 22	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀
Friction Pendulum Test:	Vacuum Stability Test:
Steel ShoeDetonatesFiber ShoeDetonates	cc/40 Hrs, at 90°C
Rifle Bullet Impact Test. Trials	- 100°C 0.4
	120°C 0.3
Explosions	135°C 150°C
Burned	200 Gram Bomb Sand Test:
Unaffected	Black powder fuse 11.1
Explosion Temperature: °C Seconds, 0.1 (no cap used)	Sensitivity to Initiation: Minimum Detonating Charge, gm
1	Mercury Fulminate Trace*
5 Explodes 282	Lead Azide Trace*
10 276	* <.001 gm, alternative
15 272 20 267	Ballistic Mortar, % TNT:
20 201	Trauzi Test, % TNT: (a) 40
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method
100°C Heat Tost	Condition
% Loss let 48 Hrs 0.28	Confined
% Loss 2nd 48 Hrs 0.73	Density, gm/cc
Explosion in 100 Hrs None	Brisance, % TNT
Flammability Index:	Detonation Rate: Confinement
Hygroscopicity: % 25°C, 100% RH 0.05	- Condition Charge Diameter, in.
Jo 0, 70% m 0.02	Density, gm/cc 2.9
volatility:	Rate, meters/second 5200

Lead Styphnate

Fragmentation Test:	Shaped Charge Effectiveness, TNT =	100:		
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Stee Hole Volume Hole Depth	I Cones		
Total No. of Fragments: For TNT	Color: Orange-reddish	Color: Orange-reddish brown Principal Uses: Igniting charge, and ingredient of priming compositions		
For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib	Principal Uses: Igniting charge of priming comp			
Total No. of Fragments: For TNT	Method of Loading:	Pressed		
For Subject HE	Loading Density: gm/cc	n de lander Anne Stan		
Fragment Velocity: ft/sec At 9 ft At 25½ ft	Storage:	11111111250AU 2010		
Density, gm/cc	Method	Wet		
Blast (Relative to TNT):	Hazard Class (Quantity-Distance)	Class 9		
Air: Peak Pressure Impulse Energy	Compatibility Group Exudation	Group M (wet) None		
Air, Confined: Impulse	Activation Energy: kcal/mol	75.39		
Under Water: Peak Pressure Impulse	Induction Period, sec <u>Specific Heat: cal/cm/^OC</u>	0.5-10 (c)		
Energy				
Underground: Peak Pressure Impulse	-50 0 25 50	0.141 0.158 0.164 0.167		
Energy		 I. S. C. S. T. Schlader, 194 		
Heat of:	In the second	nd - Filledommedia		
Combustion, cal/gm 1251 Explosion, cal/gm 457 Gas Volume, cc/gm 368 Formation, cal/gm -92		Hygerseyjal (* ' Velasiyasiya'''''''''''''''''''''''''''''''		

Preparation:



Dissolve 14.4 gm lead nitrate and 1 cc of 36% acetic acid in 320 cc distilled water. Dissolve 4 gm 2,4,6-trinitroresorcinol and 1.73 gm sodium carbonate in 80 cc distilled water. Add the lead acetate solution to the trinitroresorcinol solution, under agitation, keeping the temperature at $70^{\circ}-75^{\circ}$ C and continue stirring for 3 hours at this temperature. Cool to 20° C in 5 hours. Evaporate the solution to 1/3 its volume, cool, filter and wash the product well with water (to neutrality).

Sensitivity to Static Discharge, joules: (b)	0.0009
Loss in Weight at 105 ⁰ C: %	
3 hours 6 hours 9 hours	0.02 0.23 0.23
Effect of Storage for 2 Months at 80°C, on:	
Explosion Temperature Test Value Sand Test Value Sensitivity to Initiation	Nil Nil Nil

Solubility, gm/100 gm (%) in:

Glycol	Diacetate
°C	<u>%</u>
20-25	0.1

Origin:

First described in 1914 by von Hurtz and found to be a relatively poor initiator by Wallbaum in comparison to other primary explosives. (Z ges Schiess Sprengstoffw <u>34</u>, 126, 161, 197 (1939)). Moisak showed that lead styphnate could be used as an insulating (cover) material for lead azide providing protection from mechanical and chemical influences and, at the same time, increasing the detonating ability of the total charge (Transactions of Butlerov Inst Chem Tech Kasan (Russia) 2, 81-5 (1935).

Lead Styphnate

Destruction by Chemical Decomposition:

Lead styphnate is decomposed by dissolving it in at least 40 times its weight of 20% sodium hydroxide or 100 times its weight of 20% ammonium acetate and adding a solution of sodium dichromate, equal to half the weight of styphnate and 10 parts of water.

References: 41

(a) Report AC-956/Org Ex 74.

(b) F. W. Brown, D. H. Kusler and F. C. Gibson, <u>Sensitivity of Explosives to Initiation by</u> <u>Electrostatic Discharges</u>, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

(c) C. Lenchitz, Ice Calorimeter Determination of Enthalpy and Specific Heat of Eleven Organometallic Compounds, PATR No. 2224, November 1955.

(d) Also see the following Picatinny Arsenal Technical Reports on Lead Styphnate:

<u>o</u>	<u>1</u>	2	<u>3</u>	24	6	7	8	2
1450 2220	11	1352 2032	453 2093	2164	1316	407 1737 2077	318	2179

⁴¹See footnote 1, page 10,

Mannitol Hexanitrate (Nitromannite)

Composition:	Molecular Weight: (C ₆ H ₈ N ₆ 0 ₁₈) 452
$\begin{array}{cccc} & & & & & & \\ & & & & & \\ C & 15.9 & & & \\ & & & & & \\ & & & & & \\ \end{array}$	Oxygen Balance: 7.1 CO ₂ % 7.1 CO % 28.3
H 1.0 L HCONO	Density: gm/cc 1.73
N LO.O HCONO	Melting Point: °C
C/H Ratio 0.133	Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 11	Boiling Point: °C Decomposes 150
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 4 Sample Wt, mg 11	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀
Friction Pendulum Test:	Vacuum Stability Test:
Steel ShoeDetonatesFiber ShoeUnaffected	cc/40 Hrs, at 90°C
Rifle Bullet Impact Test: Trials	120°C
%	135°C
Explosions	150°C
Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm 68.5
Explosion Temperature: °C Seconds, 0.1 (no cap used) 160-170 (a)	Sensitivity to Initiation: Minimum Detonating Charge, gm
1 232 (b)	Mercury Fulminate
5 175 (c)	Lead Azide 0.06
15	letryl
20	Ballistic Mortar, % TNT:
	Trauzi Test, % TNT: (c) 172
75°C International Heat Test:% Loss in 48 Hrs0.4	Plate Dent Test: Method
100°C Heat Test:	Condition
% Loss, 1st 48 Hrs	Confined
% Loss, 2nd 48 Hrs	Density, gm/cc
Explosion in 100 Hrs (Frothed) 48 hours	Brisance, % INI
Flammability Index:	- Detonation Rate: (d) Confinement Yes
Hygroscopicity: % 30°C, 90% RH 0.17	Condition Pressea Charge Diameter, in. 0.5
Volatility:	Density, gm/cc 1.73 Rote meters/second 8260

Fragmentation Test:	Shaped Charge Effectiveness, TNT $=$ 100:		
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Cones Hole Volume Hole Depth		
Total No. of Fragments: For TNT	Color:		
For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib	Principal Uses: Secondary charge in detonators (ref i), and in blasting caps designed to be initiated by a fuse (ref j)		
Total No. of Fragments: For TNT For Subject HE	Method of Loading: Pressed		
	Loading Density: gm/cc		
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry		
Blast (Relative to TNT):	Hazard Class (Quantity-Distance) Class 9		
Air: Peak Pressure Impulse Energy	Compatibility Group Exudation None		
Air, Confined: Impulse	<u>65.5°C KI Test:</u> Minutes 6		
Under Water: Peak Pressure	Heat of: (e, f, g)		
Impulse Energy	Combustion, cal/gm 1515 1525 Explosion, cal/gm 1390 1454 1468 1520 Formation, cal/gm 337 345 366		
Underground: Peak Pressure			
Energy			
	, and an internet of the second se		
	in the second		
	Variationy		

Solubility:

- a. Insoluble in water.
- b. Slightly soluble in cold alcohol (2.9 gm at 13°C).
- c. Slightly soluble in ether (4 gm at 9°C).
- d. Very soluble in hot alcohol.

Preparation: (Laboratory Method) (k)

a. Cool to below 0°C, 50 gm of 98%-100% nitric acid placed in a 300 milliliter Erlenmeyer Pyrex flask provided with a thermometer and immersed in an ice-salt mixture.

b. Introduce in small portions, 10 gm of d-mannitol, while swirling the flask to break up any lumps of mannite which might form. Keep the temperature below 0°C.

c. After solution is complete, add 100 gm of concentrated sulfuric acid from a dropping funnel, swirling the flask in an ice-salt mixture to keep the temperature below 0°C.

d. Filter the resulting porridge-like slurry through a filter paper previously hardened by treatment with mixed acid.

e. Rinse the precipitate directly on the filter with water followed by dilute aqueous sodium carbonate and finally with water. (The resulting crude mannitol hexanitrate gives 18.2% N as determined by the nitrometer.)

f. Dissolve the crude mannitol hexanitrate in boiling alcohol and filter through a waterheated funnel.

g. Bring the filtrate to boiling and gradually add hot water until the appearance of the first turbidity.

h. Cool in an ice-salt bath, separate and dry the crystals. (Yield should be about 23 gm of material, melting at $112^{\circ}-113^{\circ}C$ and having 18.58% N, the nitrogen being determined by the nitrometer. Theoretical yield would be 24.8 gm.)

Origin:

Mannitol hexanitrate was discovered in 1847 by Ascanio Sobrero who recommended it as a substitute for mercury fulminate in percussion caps (<u>Comp rend</u>, 1847, 121). It is the hexanitric ester of d-mannitol which is widely distributed in nature, particularly in the plant Fraxinus ornus. N. Sokoloff, a Russian chemist, investigated the explosive properties of HM and recommended in 1878 a method of preparation. Mannitol hexanitrate was thoroughly studied by Berthelot, Sarran and Vieille, Domonte, Menard, Strecker, Tichanowich (Ph. Naoum, <u>Nitroglycerin and</u> <u>Nitroglycerin Explosives</u>, Baltimore, 1928, pp. 156, 247-250), and particularly by J. H. Wigner (Ber <u>36</u>, 796 (1903)). More recent data have been reviewed by Guastalla and Racciu ("Modern Explosives," Industria Chimica <u>8</u>, 1093-1102 (1933)).

References:42

(a) G. C. Hale, Abstract of Available Information on the Preparation and Explosive Properties of Hexanitromannite, PA Special Report No. 238, 30 July 1925.

42See footnote 1, page 10.

(b) C. A. Taylor and W. H. Rinkenbach, "Sensitiveness of Detonating Compounds to Frictional Impact, Impact, and Heat," J. Frank Inst <u>204</u>, 369-76 (1927).

(c) Ph. Naoum, Z ges Schiess - Sprengstoffw (Munich), pp. 181, 229, 267 (27 June 1932).

(d) H. Kast, Z angew Chem, <u>36</u>, 74 (1923).

(e) A. Schmidt, Z ges Schiess - Sprengstoffw 29, 262, (1934).

Landolt and Börnstein, E III, p. 2914.

(f) A. Marshall, Explosives, Their Manufacture, Properties, Tests, and History, Vol III, London (1932) p. 39. Ph. Naoum, <u>Nitroglycerin and Nitroglycerin Explosives</u>, Baltimore, (1928), pp. 156, 247-250.

(g) A. Schmidt, Z ges Schiess - Sprengstoffw 29, 262 (1934) G. Fleury, L. Brissand and P. Lhoste, "Structure and Stability of Nitric Esters," Comp rend 224, 1016-18 (1947). W. R. Tomlinson, Jr., Fundamental Properties of High Explosives. Thermodynamic Relations for Use in the Estimation of Explosive Properties, PATR No. 1651, 22 April 1947.

(h) Sarran and Vielle, Mém poudr 2, 161 (1884-1889).

- (i) E. von Hurtz, U. S. Patent 1,878,652 (20 September 1932).
- (j) L. A. Burrows, U. S. Patent 2,427,899 (23 September 1947).

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(k) B. T. Fedoroff, <u>Handbook of Explosives and Related Items</u>, Picatinny Arsenal (unpublished).

(1) O. E. Sheffield, Literature Survey on Mannitol Hexanitrate, PA Chemical Research Laboratory Report No. 52-IM1-16, 23 January 1952.

(m) Also see the following Picatinny Arsenal Technical Reports on Mannitol Hexanitrate:

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<u>2</u> 1352

Composition:	Molecular Weight: (HgC ₂ N ₂ O ₂) 285			
$\begin{array}{ccc} c & 8.4 \\ N & 9.8 \end{array} \qquad \qquad 0 - N = c \\ Hg \end{array}$	Oxygen Balance: -17 CO % -5.5			
0 11.2 $0 - N = C$	Density: gm/cc Crystal 4.43			
Нд 70.6	Melting Point: °C Decomposes			
C/H Ratio	Freezing Point: °C			
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus cm 5: (1 kg wt) 25	Boiling Point: °C			
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 2; (1 1b wt) 4 Sample Wt, mg 30	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀			
Friction Pendulum Test:Steel ShoeExplodesFiber ShoeExplodes	Vacuum Stability Test: cc/40 Hrs, at 90°C			
Rifle Bullet Impact Test: Trials % Explosions Partials	- 100°C Explodes 120°C 135°C 150°C			
Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm Black powder fuse 23.4			
Explosion Temperature:°CSeconds, 0.1 (no cap used)26312395Explodes2101019915194	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl			
20 190	Ballistic Mortar, % TNT:			
75°C International Heat Test: % Loss in 48 Hrs0.18	Trauzi Test, % TNT: (a) 51 Plate Dent Test: Method			
 100°C Heat Test: Exploded in 16 hours % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs 	Condition Confined Density, gm/cc Brisance, % TNT			
Flammability Index:	Detonation Rate: Confinement			
Hygroscopicity: % 30°C, 90% RH 0.02	Condition Pressed Charge Diameter, in.			
Volatility:	Density, gm/cc 2.0 3.0 4.0 Rate, meters/second 3500 4250 5000			

Mercury Fulminate

Fragmentation Test:	Shaped Charge Effectiveness, TNT =	100:
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones Steel	Cones
Density, gm/cc	Hole Volume	
Charge Wt. Ib	Hole Depth	
		e de altre de la companya de la comp
Total No. of Fragments:	Color: White	to gray
For TNT	tioner 1	1.1.1 B. 1.1.
For Subject HE	Principal Uses: Detonators and i	ngredient of
3 inch HE, M42A1 Projectile, Lot KC-5:	priming composite	10115
Density, gm/cc		
Charge Wt, Ib		
Total No. of Fragments:	Mathed of Loading, psi x 10 ³	
For TNT	3 5 10 12	15 20
For Subject HE	3.00 3.20 3.60 3.70	3.82 4.00
	Loading Density: gm/cc	
Fragment Velocity: ft/sec		i ny dia materia sula
At 9 ft	Storage:	
Density, gm/cc	Method	Wet
	2442 (2727).	
Blast (Relative to TNT):	Hazard Class (Quantity-Distance)	Class 9
and the second	Compatibility Group	Group M (wet
Air: Peak Pressure		a series and the series and
Impulse	Exudation	None
Eperav	5 A	0.0
Lifergy	Stab Sensitivity:	
Air, Confined:	Density Firing Point (in	nch-ounces)
Impulse	gm/cc 0% 50%	100%
	3.91 3.2 4.3	5.5
Under Water: Peak Pressure	4.26 1.6 2.6	5.5
Impulse	4.50 1.6 2.5	4.0
Energy	Activation Energy:	
	kcal/mol	29.81
Underground:	Induction Period, sec	0.5-10
Peak Pressure	Heat of:	
Impulse	Combustion, cal/gm	938
-	Explosion, cal/gm	243
Energy		206
Energy	Formation, cal/gm	-220
Energy	Formation, cal/gm Specific Heat: cal/gm/ ^o C	1.1
Energy	Formation, cal/gm Specific Heat: cal/gm/ ^O C Thermal Conductivity:	1.1

Initiating Efficiency; Grams Required to Give Complete Initiation of:

	Fulminate, gm
TNT	0.25
Tetryl	0.20
RDX	0.19
PEIN	0.17

Compatibility with Metals:

Dry: Reacts rapidly with aluminum and magnesium. Reacts slowly with copper, zinc, brass and bronze. Iron and steel are not affected.

Wet: Reacts immediately with aluminum and magnesium. Reacts rapidly with copper, zinc, brass and bronze. Iron and steel are not affected.

Sensitivity	to Static	Discharge,	Joules:	(b)	0.02
and the second se			and the second se		

The Effect of Storage at 50°C (Dry) on the Purity of Mercury Fulminate

Months		Recrystall	ized Lots		Uncrystall	Uncrystallized Lots	
Storage	<u>979</u>	<u>980</u>	<u>981</u>	<u>982</u>	505.6-7/31	505.3-5711	
0]1	99•75	99.77	99•79	99.79	98.86	-0 -	
6	99•38	99.45	99.54	99.47	95.95	98.7 98.7	
9					94.95	97.4	
12 13 14	98.74 98.26 98.22	99.56	97.49	99.06 98.79	90.65	94.9	
15 16	97.52 97.00	99.30	99.30 99.01	98.19 97.75	83.76		
17	95.70	98.66		96.69			
18 23 26	94.81	98.58	98.46	95.90	79.99 74.52 63.80		

Chemistry:

Mercuric fulminate readily decomposes in the presence of aqueous solutions, chlorides, carbonate and many other materials. Due to the presence of small amounts of mercury, formed by exposure to light or elevated temperatures, it readily forms amalgams with copper, brass and bronze, thus components containing these metals must be protectively coated if used with fulminate.

Solubility, Grams of Mercur	Fulminate in	n 100	Grams	of Water	(%)
-----------------------------	--------------	-------	-------	----------	-----

°C	2
12	0.07
49	0.18

Preparation:

(Chemistry of Powder and Explosives, Davis) $CH_3 - CH_2 - OH \longrightarrow CH_3 - CHO \longrightarrow CH_2 - CHO \rightleftharpoons CH - CHO$ NO N - OH NO2 NO₂ H с-соон 🗧 CH-COOH CH 0 N N - OH Ν N -OH OH C ---> Hg(ONC)

Five gm mercury is dissolved in 25 cc of nitric acid (sp gr 1.42) without agitation, and this solution poured into 50 cc of 90% ethyl alcohol, resulting in a vigorous reaction, attended by evolution of white fumes and subsequent appearance of fulminate crystals. Red fumes then appear as precipitation of the product accelerates, and then white fumes again are evolved as the reaction moderates. After about 20 minutes the reaction is over; water is added, and the crystals are repeatedly washed, by decantation, with water to remove all acidity. The product is purified, rendered white, by solution in strong ammonium hydroxide, followed by reprecipitation with 30% acetic acid.

Origin:

Mercury fulminate was first prepared by John K. von Lowenstern (1630-1703) and in 1800 its preparation and properties were first described in detail by Edward Howard in a paper presented to the Royal Society of London (Phil Trans, 204 (1800). It was 1867 before the compound was used as an initiating agent, when Alfred Nobel invented the blasting cap and used mercury fulminate to detonate nitroglycerin (British Patent 1345 (1867)).

Destruction by Chemical Decomposition:

Mercury fulminate is decomposed by adding it, while stirring, to at least 10 times its weight of 20% sodium thiosulfate. Some poisonous cyanogen gas may be evolved.

References: 43

(a) Ph. Naoum - Z ges Schiess-Sprengstoffw (Munich), pp. 181, 229, 267 (27 June 1932).

(b) F. W. Brown, D. H. Kusler, and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

⁴³See footnote 1, page 10.

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(c) Also see the following Picatinny A	rsenal I	lechnical R	eports on	Mercury	Fulminate:
<u>0 1 2 3</u>	4	<u>5</u> <u>6</u>	<u>7</u>	8	2
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	44 94 1 34 2 94 3 84 4 74 4 04 13	65 266 05 366 55 556 85 566 65 866 15 986 25 1316 25 1486 65 1556 2146	277 297 407 537 567 637 857 1737	28 78 278 318 788 1838	199 609 749 849 999 1079 1389 2179

AMCP 706-177 Metriol Trinitrate (MTN) Liquid (or Trimethylolethane Trinitrate)

Composition:	Molecular Weight: $(C_5H_9N_3O_9)$	255
% C 23.5 0 NO-CH	Oxygen Balance:	- 35
	CO %	- 3
H 3.5 $o_2 \text{NO} - \text{CH}_2$ $c - \text{CH}_3$	Density: gm/cc Liquid	1.47
N 16.6 $O_2 NO - CH_2$	Melting Point: °C	-3
$0 \qquad 90.4$	Freezing Point: °C	
Impact Sensitivity 2 Kg Wt:	Boiling Point: °C	14
Bureau of Mines Apparatus, cm 47; (1 1b wt) 4 Sample Wt 20 mg	Refractive Index, n ^D ₂₀	
Picatinny Arsenal Apparatus, in.	n ^D ₂₅	1.4752
Sample Wt, mg 20	n ₃₀ ^D	
Friction Pendulum Test:	Vacuum Stability Test:	
Steel Shoe Explodes	cc/40 Hrs, at	
Fiber Shoe	100°C cc/m 1.9	
Rifle Bullet Impact Test: Trials	120°C	
%	135°C	
Explosions	150°C	
Partials		
Burned	200 Gram Bomb Sand Test:	43.7
Unattected		5 1
Explosion Temperature: °C	Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)	Marcuny Fulminate	
5 Ignites 235	Lead Azide	
10	Tetryl	
15		
20	Ballistic Mortar, % TNT: (a)	136
	Trauzi Test, % TNT: (b)	140
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method	
	Condition	
100°C Heat Test:	Confined	
% Loss, 1st 48 Hrs 2.5	Density, gm/cc	
% Loss, 2nd 48 mrs ⊥.8	Brisance, % TNT	
Explosion in LUU Hrs None	- Detonation Pate:	
Flammability Index:	Confinement	
	- Condition	
Hygroscopicity: % 30 [°] C, 90% RH 0.07	Charge Diameter, in.	
	Density, gm/cc	
Volatility: 60°C, mg/cm ⁻ /hr 24	Rate, meters/second	

Metriol Trinitrate (MTN) Liquid

Fragmentation Test:	Shaped Charge Effectiveness, TNT $=$ 100:
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Cones Hole Volume Hole Depth
Total No. of Fragments: For TNT	Color: Oily, slightly turbid
For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib	Principal Uses: Ingredient of rocket and double base propellants
Total No. of Fragments: For TNT	Method of Loading:
For Subject HE	Loading Density: gm/cc
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Liquid
Blast (Relative to TNT):	Hazard Class (Quantity-Distance)
Air: Peak Pressure Impulse Energy	Compatibility Group Exudation
Air, Confined: Impulse	Solubility in Water, gm/100 gm, at:
Under Water: Peak Pressure	25 [°] C <0.015 60 [°] C <0.015
Impulse -	Heat of:
Energy	Combustion, cal/gm 2642
Underground: Peak Pressure	Hydrolysis, % Acid:
Impulse Energy	10 days at 22°C 0.018 5 days at 60°C 0.115
	and service of discovery weathing a

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Preparation:

Metriol (trimethylolmethylmethane) is obtained by the following procedure, based on work by Hosaeus (Annalen 276, 76 (1893):

Into a 5 liter round bottom flask is weighed 2700 gms of water. To this are added 267 gms of 36% formaldehyde and 60 gms of propionaldehyde. The mixture is stirred for a few seconds. To the mixture is added 150 gms of calcium oxide previously slaked with 600 gms of water. The mixture is heated in boiling water for four hours, and then allowed to cool spontaneously overnight. After filtering off the insoluble calcium hydroxide, the solution is heated and treated with a saturated aqueous solution of oxalic acid to precipitate all the calcium. The precipitated calcium oxalate is filtered off, and the pale-yellow filtrate concentrated as much as possible on the steam bath to a thick lemon-yellow syrup. After dissolving in absolute alcohol, the solution is filtered and concentrated in the steam bath to about twice the volume of the concentrated syrup. The solution is then chilled in a cold box to hasten crystallization. After allowing it to warm up to just above 0°C, the mixture is filtered. The melting product is not sufficiently pure and is recrystallized from absolute alcohol. The melting point of the product (40.3 gm) is then about 196°C (Hosaeus gives 199°C).

Metriol is nitrated by carefully mixing it with 3.5 parts of $65/35 \text{ HNO}_3/\text{H}_2\text{SO}_4$ maintained at 20°C, stirring for 30 minutes, cooling to 5°C, and pouring the reaction mixture on ice. It is extracted with ether, water-washed, and adjusted to pH 7 by shaking with a sodium bicarbonate solution and again water-washed three times. It is then dried with calcium chloride, filtered, and freed of ether by bubbling with dry air until minimal rate of loss in weight is attained. The yield is 88% of the theoretical. The product has a nitrate-nitrogen content of 16.35% (calculated: 16.47%). Its refractive index at 25°C is 1.4752.

Origin:

MIN, according to Italian sources, was first prepared and patented by Bombrini-Parodi-Delfino Company of Italy under the name "metriolo." A German Patent of 1927 also describes the preparation and gives some properties. This compound was known in France before World War II under the name of "Nitropentaglycerin" and Burlot and Thomas determined its heat of combustion (Ref b).

References: 44

(a) A. H. Blatt, <u>Compilation of Data on Organic Explosives</u>, OSRD Report No. 2014, 29 February 1944.

(b) E. Burlot and M. Thomas, Mem poudr 29, 262 (1939).

(c) Also see the following Picatinny Arsenal Technical Reports on Metriol Trinitrate: 1616 and 1817.

⁴⁴See footnote 1, page 10.

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Composition:	Molecular Weight: 71
Ammonium Nitrate 40	Oxygen Balance: CO.2 % -38 CO % -20
TNT: 40 and the second se	Density: gm/cc 1.62-1.68
Aluminum 20	Melting Point: °C
C/H Ratio	Freezing Point: °C
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 13 Sample Wt, mg 17	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C
Rifle Bullet Impact Test: Trials % Explosions	- 100°C 120°C 2.1 135°C 150°C
Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 435 10	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl
20	Ballistic Mortar, % TNT: (a) 143
Representation of the second sec	- Trauzi Test, % TNT: (b) 165
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: (c) Method B
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	ConditionPressedConfinedNoDensity, gm/cc1.73Brisance, % TNT66
Flammability Index: 100	- Detonation Rate: (d) Confinement None
Hygroscopicity: %	Charge Diameter, in. 1.6
Volatility:	Density, gm/cc1.68Rate, meters/second5820

Minol-2

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	(e) Pressed 100 1.46 1.74	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH, kcal/mol) Temperature Range, °C Phase	rinkanangangan Litur (k. em Ligener A Litur (k. em Ligener A Litur (k. em
Heat of: Combustion, cal/gm	(f) 3160	Armor Plate Impact Test:	(f) and the
Explosion, cal/gm Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm	1620	60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-1b General Purpose Bombs:	828
Specific Heat: cal/gm/°C At -5 [°] C	0.30	Plate Thickness, inches	
Density, gm/cc	1.74	1	
		1 1/4 1 1/2 1 3/4	
Burning Rate: cm/sec	1989) 1999 Susan Deve S	Bomb Drop Test:	ai stiges, il julies
Thermal Conductivity: cal/sec/cm/°C Density, gm/cc	(b) 16.5 x 10 ⁻⁴ 1.74	T7, 2000-Ib Semi-Armor-Piercing	Bomb vs Concrete:
Coefficient of Expansion: Linear, %/°C	VAned in 2 - 2019 Jacob - 2019	Max Safe Drop, ft 500-Ib General Purpose Bomb vs	Concrete:
Volume, %/°C		Height, ft	
Hardness, Mohs' Scale:	terrative second of the Torrate Terration of the	- Trials Unaffected	
Young's Modulus: E', dynes/cm ²	(b) 5.03 x 10	Low Order High Order	
E, Ib/inch ² Density, gm/cc	0.73 x 10 1.66	1000-Ib General Purpose Bomb vs	Concrete:
Compressive Strength: Ib/inch ² (b) Density, gm/cc	1910-2070 1.68	- Height, ft Trials Unaffected	
Vapor Pressure: °C mm Mercury	Danayar bala serina Catalija Arter v Catalija Arter v	Low Order High Order	
			A neshanandi.

ragmentation lest:		Shaped Charge Effectiveness, TRT = 100:
90 mm HE, M71 Projectile, L	ot WC-91:	Glass Cones Steel Cones
Density, gm/cc		Hole Volume
Charge Wt, Ib		Hole Depth
Total No. of Fragments:		Color: Gray
For TNT		
For Subject HE		Principal Uses: Bombs and depth charges
3 inch HE, M42A1 Projectile,	Lot KC-5:	
Density, gm/cc		
Charge Wt, Ib		in indian de Serence val de cate a de la la la
Total No. of Fragments:		Method of Loading: Cast
For TNT		and the second states of the second states of the
For Subject HE		Loading Density: gm/cc 1.62-1.68
ragment Velocity: ft/sec		
At 9 ft At 25½ ft		Storage:
Density, gm/cc		Method Dry
last (Relative to TNT):	. Joseph La Y	Hazard Class (Quantity-Distance) Class 9
Aire des send main services		Compatibility Group Group I
Peak Pressure	115	and the second
Impulse	116	Exudation
Energy	133	
Air Confined:		Preparation:
Impulse	90	Minol is a castable mixture consisting
Under Water:		and 20 percent powdered aluminum and ther
Peak Pressure	108	fore can be prepared by adding the dry in
Impulse	126	gredients to molten TNT at 90°C under agi tion. Minol also can be prepared by addi
Energy	140	25 parts of aluminum to 100 parts of 50/5
Underground:	1 0	and out previously prepared.
Peak Pressure	134	
Impulse	139 117	
Energy	147	
		and the second

Minol-2

Origin:

Minols are British ternary explosives developed during World War II. There are three formulations:

Composition, %:	Minol-1	Minol-2	Minol-3
INT	48	40	42
Ammonium Nitrate	42	40	38
Aluminum	10	20	20

References: 45

(a) L. C. Smith and E. G. Eyster, <u>Physical Testing of Explosives</u>, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) Philip C. Keenan and Dorothy Pipes, <u>Table of Military High Explosives</u>, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.

M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.

(e) L. C. Smith and S. R. Walton, <u>A Consideration of RDX/Wax Mixtures as a Substitute for</u> Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(f) Committee of Div 2 and 8, NDRC, Report on HBX and Tritonal, OSRD No. 5406, 31 July 1945.

(g) W. R. Tomlinson, Jr., <u>Blast Effects of Bomb Explosives</u>, PA Technical Div Lecture, 9 April 1948.

(h) Also see the following Picatinny Arsenal Technical Reports on Minol-2: 1585 and 1635.

45See footnote 1, page 10.

			lio E
Composition:	All arrival to Special	Molecular Weight:	40.0
Oxidizing agent (Ammonium Perchlorate) Aluminum, atomized	35.0 26.2	Oxygen Balance: CO ₂ % CO %	-44 -37
Magnesium, atomized	26.2	Density: gm/cc Pressed	2.0
Calcium Stearate Graphite, artificial	1.9	Melting Point: °C	ald Industry
C/H Ratio	lle al el	Freezing Point: °C	di na
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	a andrós griffignasz	Boiling Point: °C	
Sample Wt 20 mg	14 M	Refractive Index, n ^D ₂₀	
Picatinny Arsenal Apparatus, in.	13	n25	
Sample Wt, mg	22	n ^D ₃₀	
Friction Pendulum Test:	winded of London	Versum Stability Test:	
Steel Shoe	Detonates	cc/40 Hrs. at	
Fiber Shoe	Unaffected	90°C	
		100°C	0.47
Rifle Bullet Impact Test: Trials		120°C	
%		135°C	
Explosions		150°C	
Partials			
Burned		200 Gram Bomb Sand Test:	10.6
Unaffected	2) and 7 Internet	Sand, gm	10.0
Explosion Temperature: °C	a series and a	Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm	
1		Mercury Fulminate	
5 285		Lead Azide	0.20
10		Tetryl	0.25
15 20		Ballistic Mortar, % TNT:	Ad. Same
	Cold Telefore	Trauzi Test, % TNT:	
75°C International Heat Test:		Plate Dent Test:	NAME AND ADDRESS OF ADDRESS OF ADDRESS ADDRESS ADDRESS ADDRESS ADDRESS ADDRESS ADDRESS ADDRESS ADDRESS ADDRESS ADDRESS ADDRESS ADDRESS ADDRESS ADDRESS
% Loss in 48 Hrs Discoloration, fumes, odor	None	Method	
100°C Hast Task		Condition	
OV Loss lot 48 list		Confined	
% Loss, 1st 48 Hrs	0.10	Density, gm/cc	
% Loss, 2nd 48 Hrs	News	Brisance, % TNT	
Explosion in 100 Hrs	wone	Distance Participation	to the second second
Flammability Index:		Confinement	
Hygroscopicity: %		Charge Diameter, in.	
Volatility:		Density, gm/cc Rate, meters/second	

MOX-1

Fragmentation Test:	Shaped Charge Effectiveness, $TNT=100$:
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc	Glass Cones Steel Cones Hole Volume
Charge Wt, Ib	Hole Depth
Total No. of Fragments: For TNT	Color: Gray powder mixture
For Subject HE	Principal Uses: Small caliber antiaircraft
3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib	projectiles
Total No. of Fragments: For TNT	Method of Loading: Pressed
For Subject HE	Loading Density: gm/cc
Fragment Velocity: ft/sec At 9 ft At 25½ ft	Storage:
Density, gm/cc	Method Dry
Blast (Relative to TNT):	Hazard Class (Quantity-Distance) Class 9
Air: Peak Pressure Impulse Energy	Compatibility Group Group I Bureau of Explosives Classification Class A Exudation
Air, Confined: Impulse	Heat of: Combustion, cal/gm 4087
Under Water: Peak Pressure Impulse	Gas volume, cc/gm 212 Performance Tests: 20 mm T215E1 Projectile:
Energy and a set of the set of th	NFOC Pressure Cube 35
Underground: Peak Pressure	APG Blast Cube 40
Impulse Energy	kcal/mol 12.5 Temp, °C 300 to 380 Time to ignition, seconds 1.78 x 10 ⁻⁴
Colorattyp yn ei i 1686: e wlaeth ee fefst 668: e wlaeth e referste	tentaia¥

Composition:	Molecular Weight: 42
% Oxidizing agent (Ammonium Perchlorate) 35.0 Aluminum, atomized 52.4	Oxygen Balance: CO ₂ % -49 CO % -43
Cupric Oxide Magnesium, atomized	Density: gm/cc Pressed 2.0
Other ingredients*9.7Calcium Stearate1.9	Melting Point: °C
*5.8% RDX and 3.9% TNT coated on Ammonium Perchlorate.	Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	Boiling Point: °C
Sample Wt 20 mg	Refractive Index, n ^D ₂₀
Sample Wt, mg 24	n ₂₅
	n ^o 30
Friction Pendulum Test:	Vacuum Stability Test:
Steel Shoe Unaffected	cc/40 Hrs, at
Fiber Shoe Unaffected	90°C
Rifle Bullet Impact Test: Trials	120°C
%	135°C
Explosions	150°C
Partials	
Burned	200 Gram Bomb Sand Test:
Unaffected	Sana, gm
Explosion Temperature: °C Seconds, 0.1 (no cap used)	Sensitivity to Initiation: Minimum Detonating Charge, gm
de fer 1 objection de la des des des des de la des des des de la des	Mercury Fulminate
5 375	Lead Azide 0.20
10	Tetryl 0.20
15	Ballistic Mortar, % TNT:
server and s	Trauzi Test, % TNT:
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test:
Discoloration, fumes, odor None	Method
100°C Heat Test:	Condition
% Loss, 1st 48 Hrs 0.27	Confined
% Loss, 2nd 48 Hrs 0.12	Density, gm/cc
Explosion in 100 Hrs None	Brisance, % TNT
Flammability Index:	Detonation Rate: Confinement
Hygroscopicity: %	- Condition Charge Diameter, in.
Volatility:	Density, gm/cc Rate, meters/second

MOX-2B

Fragmentation Test:	- kriji W valupota	Shaped Charge Effectiveness, TNT = 100:	Lephilang - 13
90 mm HE, M71 Projectile, Lo Density, gm/cc Charge Wt, Ib	t WC-91:	Glass Cones Steel Cones Hole Volume Hole Depth	gerer filter og som na de men filter men i som filter gefelse en som filter
Total No. of Fragments: For TNT		Color:	Gray
For Subject HE		Principal Uses: HE filler for small ca	liber
3 inch HE, M42A1 Projectile,	Lot KC-5:	projectiles	honul rangeri
Density, gm/cc			4 at 10 million
Charge Wt, Ib			n na stational de la composition de la Nota de la composition
Total No. of Fragments: For TNT		Method of Loading:	Pressed
For Subject TE		Loading Density: gm/cc	2.0
Fragment Velocity: ft/sec		Storage:	
At 25½ ft		Storage.	an an Isr
Density, gm/cc		Method	Dry
Blast (Relative to TNT):	H. ()	Hazard Class (Quantity-Distance)	Class 9
Air: Bare Charge: Peak Pressure Impulse	EW* EV* 1.02 1.34 1.08 1.41	Compatibility Group Bureau of Explosives Class A Exudation	Group I None
Energy Density, gm/cc	1.96	Heat of:	
Cased Charge in Air:**	1 00 1.hh	Combustion, cal/gm Explosion, cal/gm Gas volume, cc/gm	4484 1472 221
	1.16 1.53	Performance Tests:	
Energy Density.gm/cc	1.98	20 mm T215El Projectile:	29
Underground: Peak Pressure	ريان بوري ريانين . دريان بوري ريانين .	APG Blast Cube	30
Impulse		Aviation Energy:	
Energy		kcal/mol	7.6
*EW, equivalent weight as EV, equivalent volume as	compared to TNT; compared to TNT.	Temp, ^o C 340 t Time to ignition, seconds 1.39	0 470 x 10 ⁻²
**Strong paper-base phenol	ic case.		1 Stationers A

Effect	of	Altitude,	Charge	Diameter	and	Degree	of	Confinement	on	Detonation	Velocity*
		the second second second			Refe	erence a	z)				

	One-Inch Column	Two-Inch	n Column
Simulated Altitude.	Confined Unconfined	Confined	Unconfined
Feet	m/s m/s	m/s	m/s
Ground		4730	
30,000	Charge would not	4530(3)	Charge would
60,000	propagate detonation.	4430	gate detona-
90,000	do a finite second of	4.290	
Average	la la	4495	sugh "Islands" gradia

*Confined charge in 1/4" steel tube, AISI 1015 seamless, 1" diameter 18" long, and 2" diameter 7" long. All means were determined from sets of five values unless otherwise indicated by (). A 26 gm tetryl booster was used to initiate each charge.

Average Fragment Velocity at Various Altitudes* (g)

an a		S:	imulated Al	titude, Fee	t
Explosive	Charge Diameter,	Ground	30,000	60,000	90,000
Diptobile	Inches	m/s	m/s	m/s	m/s
MOX-2B,	1	2012	**	**	**
density, gm/cc 207	2	3314	3351	3247	**

*Outside diameter 2.54"; inside diameter 2.04"; length 7".

** Charge would not propagate detonation.

MOX-3B

Composition:		Molecular Weight:	45.6
Oxidizing agent (Potassium Ni Aluminum, atomized Cupric Oxide Magnesium, atomized	trate) 18 50 	Oxygen Balance: CO ₂ % CO %	-52 -43
Other ingredients* Calcium Stearate**	32 2.0	Density: gm/cc Pressed	2.0
Graphite, artificial**	1.0	Melting Point: °C	
*29.1% RDX, 0.9% wax, and 2.0 **Per cent added.	J% 11₩1•	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:	4197 I.P. 1694	Boiling Point: °C	-
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	17 24	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	
Friction Pendulum Test:	South Routers	Vacuum Stability Test:	5 ° 0
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	
Pille Pullet Impact Tests Trick	COLUMN IN W	100°C	0.57
Kirle buller impact lest: I Hais		120°C	
% Explosions		135°C	
Partials		150°C	
Burned		200 Gram Bomb Sand Test:	
Unaffected		Sand, gm	33.2
Explosion Temperature: °C Seconds, 0.1 (no cap used)	μ. 	Sensitivity to Initiation: Minimum Detonating Charge, gm	
1 1		Mercury Fulminate	
5 540		Lead Azide	0.20
10		Tetryl	0.15
15			
20		Ballistic Mortar, % INI:	
75°C International Heat Test		Trauzi Test, % TNT:	
% Loss in 48 Hrs		Plate Dent Test:	
Discoloration, fumes, odor	None	Method	
100°C Heat Test:		Condition	
% Loss, 1st 48 Hrs	0.35		
% Loss, 2nd 48 Hrs	0.13	Density, gm/cc	
Explosion in 100 Hrs	None		
Flammability Index:	1	Detonation Rate: Confinement	
		- Condition	
Hygroscopicity: %		Charge Diameter, in.	
V 1		Density, gm/cc	
Volatility:		Rate, meters/second	

MOX-3B

Fragmentation Test:	and the second second	Shaped Charge E	ffectiveness, Tl	NT = 100:	-top-of5
90 mm HE, M71 Projectile Density, gm/cc Charge Wt, Ib	, Lot WC-91:	Hole Volume Hole Depth	Glass Cones	Steel Cones	
Total No. of Fragments: For TNT		Color:	Gray	powder mixt	ure
For Subject HE		Principal Uses:	Small calib	er antiairo	raft
3 inch HE, M42A1 Projecti Density, gm/cc Charge Wt, Ib	le, Lot KC-5:		projectiles		
Total No. of Fragments: For TNT		Method of Loadi	ng:		Pressed
For Subject HE	En The Contract	Loading Density: At 30,000 ps:	gm/cc i		~ 2.0
At 9 ft At 251/2 ft		Storage:		itali itaani	ternet stille
Density, gm/cc		Method			Dry
Blast (Relative to TNT):	a data da una mangéria di Tanta. Seria, qu	Hazard Class	(Quantity-Dista	nce)	Class 9
Air: Peak Pressure Impulse Eperay		Compatibility	Group Bureau of E	Xplosives (Group I Class A
Air, Confined: Impulse		Heat of: Combustio	n, cal/gm		4331
Under Water: Peak Pressure		Gas vol	ume, cc/gm		232
Impulse		Performance 20 mm T21	Tests: 5El Projecti	le:	
Underground:		NFOC Pres APG Blast	sure Cube Cube		37 52
Impulse		Activation E	nergy:		
Energy		kcal/mol Temp, ^O C Time to i seconds	gnition,	Values n due to e nition u tions of	ot included rratic ig- nder condi- test.
					n. diffusie V

MOX-4B

70 Oxygen Balance: Aluminum, atomized 50 Oupric Oxide Magnesium, atomized Other ingredients* 32 Calcium Stearate** 2.0 Medresium, atomized Other ingredients* 32 Calcium Stearate** 2.0 Mediting Point: °C Pressed *29.1% RDX, 0.9% wax, and 2.0% TNT. **Per cent added. Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 78 Sample Wt 20 mg Refractive Index, n20 Picatinny Arsenal Apparatus, in. 18 Sample Wt, mg 26 Nifle Bullet Impact Test: Trials % 100°C 0.67 Rifle Bullet Impact Test: Trials % 135°C Sample Wt, mg 200 Gram Bomb Sand Test: Solitis 100°C % 150°C Seconds, 0.1 (no cop used) Mercury Fulminate 1	
Density: Density: gm/cc Pressed 2.0 Calcium Stearate** 2.0 Melting Point: °C Pressed 2.0 Calcium Stearate** 2.0 Melting Point: °C Pressed 2.0 Calcium Stearate** 2.0 Melting Point: °C Pressed 2.0 **Per cent added. Freezing Point: °C Freezing Point: °C Pressed 2.0 Impact Sensitivity, 2 Kg Wt: Boiling Point: °C Refractive Index, n ^D ₂₀ Pressed 2.0 Sample Wt 20 mg 26 n ^D ₂₅ n ^D ₂₅ Pressed 2.0 Picatinny Arsenol Apparatus, in. 18 n ^D ₂₅ n ^D ₂₅ Sample Wt, mg 26 n ^D ₂₅ Friction Pendulum Test: Steel Shoe Sparks cc/40 Hrs, at Fiber Shoe Unaffected 90°C 100°C 0.67 120°C 100°C 135°C 135°C 200 Gram Bomb Sand Test: Unaffected 200 Gram Bomb Sand Test: 33.6 Burned 200 Gram Bomb Sand Test: Minimum Detonating Charge, gm Unaffected Minimum Detonating Charge, gm	
Graphite, artificial** 1.0 *29.1% RDX, 0.9% wax, and 2.0% TNT. **Per cent added. Impact Sensitivity, 2 Kg Wt: Bureou of Mines Apporatus, cm 78 Sample Wt 20 mg Boiling Point: °C Pricatinny Arsenal Apporatus, in. 18 Sample Wt, mg 26 Friction Pendulum Test: Steel Shoe Steel Shoe Sparks Fiber Shoe Unaffected % 1.0°C 8 90°C % 1.35°C Explosions % Partials 150°C Burned 200 Gram Bomb Sand Test: Unaffected Sand, gm Explosion Temperature: °C Seconds, 0.1 (no cap used) Minimum Detonating Charge, gm 1	
*29.1% RDX, 0.9% wax, and 2.0% TNT. **Per cent added. Impact Sensitivity, 2 Kg Wt: Bureou of Mines Apparatus, cm 78 Sample Wt 20 mg 78 Picatiny Arsenal Apparatus, in. 18 Sample Wt, mg 26 Friction Pendulum Test: 26 Steel Shoe Sparks Fiber Shoe Unaffected % 100°C Sample Steel Shoe Sparks Fiber Shoe Unaffected % 120°C % 135°C Explosions 90 Partials 200 Gram Bomb Sand Test: Sand, gm 33.6 Explosion Temperature: °C Seconds, 0.1 (no cap used) 1	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 78 Bureau of Mines Apparatus, cm 78 Sample Wt 20 mg Refractive Index, n ^D ₂₀ Picatinny Arsenal Apparatus, in. 18 Sample Wt, mg 26 Friction Pendulum Test: 26 Steel Shoe Sparks Fiber Shoe Unaffected 90°C 100°C 0.67 Rifle Bullet Impact Test: Trials Burned 9% Unaffected 135°C 90°C 100°C 0.67 135°C 135°C 135°C 150°C 200 Gram Bomb Sand Test: 33.6 Explosions Sand, gm 33.6 Explosion Temperature: °C Sensitivity to Initiation: Seconds, 0.1 (no cap used) Minimum Detonating Charge, gm 1 Mercury Fulminate	
Sample Wt 20 mg Refractive Index, n ^D ₂₀ Picatinny Arsenal Apparatus, in. 18 Sample Wt, mg 26 Friction Pendulum Test: Vacuum Stability Test: Steel Shoe Sparks Fiber Shoe Unaffected Rifle Bullet Impact Test: Trials % 135°C Explosions 135°C Partials 150°C Burned 200 Gram Bomb Sand Test: Unaffected Sand, gm 1 1	
Friction Pendulum Test: Sparks Vacuum Stability Test: Steel Shoe Sparks cc/40 Hrs, at Fiber Shoe Unaffected 90°C Rifle Bullet Impact Test: Trials 100°C Rifle Bullet Impact Test: Trials 120°C % 135°C 135°C Explosions 150°C 200 Gram Bomb Sand Test: Burned Sand, gm 33.6 Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 Minimum Detonating Charge, gm 1 Mercury Fulminate	
Steel Shoe Sparks cc/40 Hrs, at Fiber Shoe Unaffected 90°C Rifle Bullet Impact Test: Trials 100°C 0.67 Rifle Bullet Impact Test: Trials 135°C Partials 150°C 200 Gram Bomb Sand Test: Burned Sand, gm 33.6 Explosion Temperature: °C Sensitivity to Initiation: Seconds, 0.1 (no cap used) Minimum Detonating Charge, gm 1 Mercury Fulminate	
Fiber Shoe Unaffected 90°C Rifle Bullet Impact Test: Trials 100°C 0.67 Rifle Bullet Impact Test: Trials 135°C Partials 150°C 200 Gram Bomb Sand Test: Burned Sand, gm 33.6 Explosion Temperature: °C Sensitivity to Initiation: Seconds, 0.1 (no cap used) Minimum Detonating Charge, gm 1 Mercury Fulminate	
Rifle Bullet Impact Test: Trials 0.67 Rifle Bullet Impact Test: Trials 120°C % 135°C 150°C Partials 200 Gram Bomb Sand Test: 33.6 Burned Sand, gm 33.6 Unaffected °C Sensitivity to Initiation: Seconds, 0.1 (no cap used) Minimum Detonating Charge, gm 1 Mercury Fulminate	
% 120°C % 135°C Partials 150°C Burned 200 Gram Bomb Sand Test: Unaffected Sand, gm Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 Minimum Detonating Charge, gm Mercury Fulminate	
Explosions 153 °C Partials 150 °C Burned 200 Gram Bomb Sand Test: Unaffected Sand, gm Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 Minimum Detonating Charge, gm 1	
Partials 200 Gram Bomb Sand Test: Burned Sand, gm Unaffected Sand, gm Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 Mercury Fulminate	
Burned 200 Gram Bomb Sand Test: Unaffected Sand, gm Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 Mercury Fulminate	
Unaffected Sand, gm 33.6 Explosion Temperature: °C Sensitivity to Initiation: Seconds, 0.1 (no cap used) Minimum Detonating Charge, gm 1 Mercury Fulminate	
Explosion Temperature: °C Sensitivity to Initiation: Seconds, 0.1 (no cap used) Minimum Detonating Charge, gm 1 Mercury Fulminate	A
Seconds, 0.1 (no cap used) Minimum Detonating Charge, gm 1 Mercury Fulminate	
1 Mercury Fulminate	
5 610	
Lead Azide 0.20	
15 letryl 0.15	
20 Ballistic Mortar, % TNT:	
Trauzi Test, % TNT:	
75°C International Heat Test: % Loss in 48 Here Plate Dent Test:	
Discoloration, fumes, odor None Method	
100°C Heat Test:	
% Loss, 1st 48 Hrs 0.22 Confined	
% Loss, 2nd 48 Hrs 0.12 Density, gm/cc	
Explosion in 100 Hrs None Brisance, % TNT	
Flammability Index:	
Condition	
Hygroscopicity: % Charae Diameter, in.	
Density, am/cc	
Volatility: Rate, meters/second	

220

MOX-4B

Fragmentation Test:		Shaped Charge Effectiveness, $TNT = 1$	00:
90 mm HE, M71 Projectile Density, gm/cc Charge Wt, Ib	, Lot WC-91:	Glass Cones Steel C Hole Volume Hole Depth	Cones
Total No. of Fragments: For TNT		Color: Gray 1	powder mixture
For Subject HE 3 inch HE, M42A1 Projecti Density, gm/cc Charge Wt, Ib	le, Lot KC-5:	Principal Uses: Small caliber and projectiles	tiaircraft
Total No. of Fragments: For TNT		Method of Loading:	Pressed
Fragment Velocity: ft/sec	to stH Darge	Loading Density: gm/cc At 30,000 psi	~2.0
At 9 ft At 25½ ft		Storage:	ioni tatul sha
Density, gm/cc	21 0e 1	Method	Dry
Blast (Relative to TNT):		Hazard Class (Quantity-Distance)	Class 9
Air: Peak Pressure Impulse Energy		Compatibility Group Burea	Group I u of Explosives Class A
Air, Confined: Impulse		Heat of: Combustion, cal/gm	4392
Under Water: Peak Pressure		Gas volume, cc/gm	208
Impulse Energy		20 mm T215El Projectile:	al de la calenda de la composición 1 - 1992 - Calenda de Calenda de la composición 1 - 1992 - Calenda de Calenda de la composición de la composición
Underground: Peak Pressure		NFOC Pressure Cube APG Blast Cube	43 53
Impulse		Aviation Energy:	
Energy		kcal/mol Values Temp, ^O C due to Time to ignition, tion u seconds of tes	not included erratic igni- nder conditions t.
			an bill house of

мох-бв

Composition:	Molecular Weight:	43
% Oxidizing agentAluminum, atomized49.2Cupric Oxide19.7Magnesium, atomized	Oxygen Balance: CO <u>.</u> % CO %	-50 -42
Other ingredients* 29.6	Density: gm/cc	the Table and Second
Graphite, artificial 1.5	Melting Point: °C	110 M. 110 M
C/H Ratio	Freezing Point: °C	and the second second
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	Level Mill House
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 19 Sample Wt, mg 27	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	n and the second s
Friction Pendulum Test:	Vacuum Stability Test:	
Steel ShoeUnaffecteFiber ShoeUnaffecte	ed cc/40 Hrs, at ed 90°C	
Rifle Bullet Impact Test. Trials	100°C	0.43
	120°C	
Explosions	135°C 150°C	
Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm	10.8
Explosion Temperature: °C Seconds, 0.1 (no cap used)	Sensitivity to Initiation: Minimum Detonating Charge, gr	n and an and a second
20 ma 4.23	Mercury Fulminate	to 2 hair of the
5 510	Lead Azide	0.20
10	Tetryl	0.16
20	Ballistic Mortar, % TNT:	de al la charge est l
(a) State (a) and (b) and (c) and (Trauzl Test, % TNT:	empty-Weighten)
75°C International Heat Test: % Loss in 48 Hrs 0.02/10 Discoloration, fumes, odor None) gm Plate Dent Test: Method	to damp "Al
100°C Heat Test:	Condition	
% Loss, 1st 48 Hrs 0.00	Confined	
% Loss, 2nd 48 Hrs 0.00	Density, gm/cc	
Explosion in 100 Hrs None	Brisance, % INI	
Flammability Index:	Detonation Rate: Confinement	
Hygroscopicity: % 30°C, 90% RH, two weeks 0.79	Condition Charge Diameter, in.	
Volatility:	Rate, meters/second	

ragmentation Test:	Shaped Charge Effectiveness, TNT = 100:
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb	Glass Cones Steel Cones Hole Volume Hole Depth
Total No. of Fragments: For TNT	Color: Gray powder mixture
For Subject HE	Principal Uses: Small caliber antiaircraft
3 inch HE, M42A1 Projectile, Lot KC-5:	projecorreb
Density, gm/cc	training welling reaching a solution of the second state welling we
Charge Wt, Ib	a a la suite a suite and sense a suite a suite a
Total No. of Fragments:	Mathad of Londing: Pressed
For TNT	Method of Loading:
For Subject HE	anna actairean anna 116 feathr
	Loading Density: gm/cc
ragment Velocity: ft/sec	At 30,000 psi ~2.0
At 9 ft At 25½ ft	Storage:
Density, gm/cc	Method Dry
Blast (Relative to TNT):	Hazard Class (Quantity-Distance) Class
Air: Peak Pressure	Compatibility Group Bureau of Explosive
Impulse	
Energy	
Air, Confined:	Heat of:
Impulse	Combustion, cal/gm 4293
Under Water	Explosion, cal/gm 750
Peak Pressure	Gas vorume, cc/gm 204
Impulse	Activation Energy:
Energy	kcal/mol Values not included Temp, C due to erratic igni-
Underground: Peak Pressure	Time to ignition, tion under condition seconds of test.
Impulse	n an ann an an an an ann ann ann an ann an a
Energy	
	그는 김 이 가지 않는 것이 같은 것을 다 했다. 것

Preparation:

The various ingredients used in the preparation of MOX explosives are coated separately as follows:

Dichromated Atomized Aluminum - Seventy-five grams of chemically pure grade sodium dichromate is dissolved in 1500 milliliters of water at 100°C under mechanical agitation. Six hundred grams of the atomized aluminum powder is added gradually (2 to 3 minutes) and stirring is continued for half an hour. The dichromated metal is filtered, washed with water (15 to 20 times) until the washings show only a slight cloudiness with silver nitrate. The water-wet product is then dried in an oven at 50°C. The dried material is hand-rolled to reduce any conglomerates, and blended before use.

<u>Wax-Coated RDX</u> - Eighteen grams of molten Be Square Special Wax (manufacturer's 180° to 185° Fahrenheit grade amber) is added to 582 grams of finely divided RDX (water precipitated from acetone solution) in a water slurry under mechanical agitation. The temperature of the wax-RDX slurry is maintained above the melting point of the wax (about 90°C). The stirring is continued for half an hour. After cooling to 50°C, the wax-coated RDX is recovered by filtration in a Büchner funnel and dried in air. The RDX thus coated and presumed to be 3% waxed RDX or a 97/3 RDX/wax mixture is hand-rolled to crush any conglomerates formed, and blended by hand before use.

<u>INT-Coated Barium Nitrate</u> - Thirty grams of INT in alcohol solution is added to 270 grams of barium nitrate in an alcohol slurry under agitation. The temperature of the INT-barium nitrate mixture is maintained at 80°C and stirring is continued until most of the alcohol is evaporated. The coated material is spread in a thin layer on a tray to dry in air overnight. The barium nitrate thus coated with 10% TNT is reduced to an intimate mixture by hand-rolling and blending before use.

INT-Coated Potassium Nitrate - The INT-coated potassium nitrate is prepared by the same procedure as is used for coating barium nitrate.

RDX/INT-Coated Ammonium Perchlorate - The ammonium perchlorate is coated by dissolving the appropriate weights of RDX and TNT in hot alcohol. After adding the ammonium perchlorate, the slurry is stirred until most of the solvent is evaporated. The treated ammonium perchlorate is spread on a tray to dry overnight. Agglomerates formed during the process are crushed by hand-rolling and blending the mixture before use.

<u>INT-Coated RDX</u> - Sixty grams of molten INT are added to a water slurry of 540 grams of finely divided RDX (water precipitated from acetone solution) under mechanical agitation. The temperature of the INT-RDX slurry is maintained at about 90°C and stirring is continued for half an hour. After cooling to about 50°C, the INT-coated RDX is recovered by filtration. The RDX thus treated, and presumed to be 10% coated or a 90/10 RDX/INT mixture, is further blended by hand after rolling to crush any aggregates formed during the process.

The MOX explosive mixtures are prepared by blending the appropriate weights of the dry ingredients in a Patterson-Kelly twin-shell blender for at least 30 minutes.

Origin:

MOX type explosive mixtures were developed beginning in 1950 by National Northern, technical division of the National Fireworks Ordnance Corporation, West Hanover, Massachusetts.

References: 46

(a) A. O. Mirarchi and A. T. Wilson, Development of MOX Explosives for Improved 20 mm Ammunition, Navy Contract NOrd-10975, Task 1, National Fireworks Ordnance Corporation, First Yearly Summary, August 1950 to August 1951.

(b) A. T. Wilson, Development of MOX Explosives: Various Oxidants in MOX, First Progress Report NFOC-6, Navy Contract NOrd-12382, National Fireworks Ordnance Corporation, December 1952.

(c) A. O. Mirarchi, <u>Properties of Explosives: Theory of the MOX Explosion</u>, First Progress Report NFOC-10, Navy Contract NOrd-11393, National Fireworks Ordnance Corporation, December 1952.

(d) A. O. Mirarchi, <u>Properties of Explosives: MOX Explosives in Various Atmospheres</u>, First Progress Report NFOC-9, Navy Contract NOrd-11393, National Fireworks Ordnance Corporation, 1952.

(e) A. T. Wilson, Development of MOX Explosives: Composition Variations, First Progress Report NFOC-7, Navy Contract NOrd-12382, National Fireworks Ordnance Corporation, 1952.

(f) A. T. Wilson, <u>Development of MOX Explosives: Various Oxidants in MOX</u>, Second Progress Report NFOC-14, Navy Contract NOrd-13684, National Fireworks Ordnance Corporation, October 1953.

(g) A. W. O'Brien, Jr., C. W. Plummer, R. P. Woodburn and V. Philipchuk, <u>Detonation</u> Velocity Determinations and Fragment Velocity Determinations of Varied Explosive Systems and Conditions, National Northern Corporation Final Summary Report NNC-F-13, February 1958 (Contract DAI-19-020-501-ORD-(P)-58).

(h) P. Z. Kalanski, <u>Air Blast Evaluation of MOX-2B Cased and Bare Charges</u>, NAVORD Report No. 3755, 5 April 1956.

(i) Also see the following Picatinny Arsenal Technical Reports on MOX Explosives: 1935, 1969, 2204, 2205.

⁴⁶See footnote 1, page 10.
Nitrocellulose, 12.6% N (NC)

Composition:	Molecular Weight:	(272.39) _n
$\begin{array}{c} & 26.46 \\ H & 2.78 \\ N & 12.60 \end{array} \xrightarrow{H_2C} H \\ \begin{array}{c} H_2C \\ H \\ X \end{array} \xrightarrow{H} H \\ H \\ H \end{array}$	Oxygen Balance: CO ₂ % CO %	-35 0.6
0 58.16 0 X	Density: gm/cc	
	Melting Point: °C	Decomposes
C/H Ratio 0.23	Freezing Point: °C	Land the second second
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3 Sample Wt, mg 5	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	erra meneria da contra el 1911 - Milan 1916 - Ala Milana Indonesia
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C	0.17
Rifle Bullet Impact Test: Trials % Explosions Partials	100°C 120°C 16 hours 135°C 150°C	1.0 11.+
Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm	45.0
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5. Decomposes 170	Sensitivity to Initiation: Minimum Detonating Charge, of Mercury Fulminate	gm 0.20
10	Lead Azide Tetryl	0.10
15	Ballistic Mortar, % TNT:	
, 	Trauzl Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:	— Detonation Rate: Confinement	and the stand of the stand stands
Hygroscopicity: % 30°C, 90% RH 3	 Condition Charge Diameter, in. 	
Volatility: 60°C, mg/cm ² /hr 0.0	Density, gm/cc Rate, meters/second	

Nitrocellulose, 13.45% N (NC)

AMCP 706-177

Composition:	Molecular Weight:	(286.34) _n
$\begin{array}{c ccccc} & & & & & & & \\ C & & 25.29 & & & \\ H & & 2.52 & & \\ N & & 13.45 & & X & H & \\ \end{array}$	Oxygen Balance: CO ₂ % CO %	-29 4.7
0 58.74 0 x	Density: gm/cc	
	Melting Point: °C	Decomposes
C/H Ratio 0.23	Freezing Point: °C	Contraction of the
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	pH 2 within the second
Sample Wt 20 mg	Refractive Index, n ^D ₂₀	
Picatinny Arsenal Apparatus, in. 3	n ₂₅	
Sample WT, mg	n ₃₀	
Friction Pendulum Test:	Vacuum Stability Test:	THE PARAMETER PROPERTY
Steel Shoe	cc/40 Hrs, at	0. 40
Fiber Shoe		1 5
Rifle Bullet Impact Test: Trials	100 C	1.7 11.+
	120 C	TT•.
Explosions	150°C	
Partials	150 C	a second
Burned	200 Gram Bomb Sand Test:	
Unaffected	Sand, gm	49.0
Explosion Temperature: °C	Sensitivity to Initiation:	a transmission Theorem and
Seconds, 0.1 (no cap used)	Minimum Detonating Charge	e, gm
1 230	Mercury Fulminate	0.10
10		0.10
	Tetryi	
20	Ballistic Mortar, % TNT:	125
Travel You, S. THT.	Trauzl Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method	
100°C Heat Test:	Condition	
% Loss, 1st 48 Hrs 0.3	Confined	
% Loss, 2nd 48 Hrs 0.0	Density, gm/cc	
Explosion in 100 Hrs None	Brisance, % TNT	algibilit ini talamistik
Flammability Index:	- Detonation Rate: Confinement	
Hygroscopicity: % 30° C, 90% RH ~ 2		
N. L. 1990	Density, gm/cc	1.20
Volatility: 60°C, mg/cm /hr 0.0	Rate, meters/second	7300

Composition:	Molecular Weight: (297.15) _n
$\begin{array}{cccc} c & 24.25 \\ H & 2.37 \\ N & 14.14 \end{array} \xrightarrow{H_2C}_{X} H \\ \end{array}$	Oxygen Balance: CO2 % -24 CO % 8
0 59.24 0 H	Density: gm/cc 1.65-1.70
	Melting Point: °C Decomposes
C/H Ratio 0.23	Freezing Point: °C
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3 Sample Wt, mg 5	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 1.46
Rifle Bullet Impact Test: Trials % Explosions	100°C 14 hours 11.+ 120°C 16 hours 11.+ 135°C
Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm 52.3
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate
5 10	Lead Azide 0.10 Tetryl
20 LC ***********************************	Ballistic Mortar, % TNT:
an mayor a construction of the second sec	Trauzi Test, % TNT:
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method
100°C Heat Test:	Condition
% Loss, 1st 48 Hrs	Confined
% Loss, 2nd 48 Hrs	Density, gm/cc
Explosion in 100 Hrs	Brisance, % TNT
Flammability Index:	Detonation Rate: Confinement
Hygroscopicity: % 30°C, 90% RH 🛹 1	Condition Charge Diameter, in.
Volatility: 60°C, mg/cm ² /hr 0.0	Rate, meters/second

Nitrocellulose (NC)

AMCP 706-177

90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb	Glass Cones Steel Cones Hole Volume Hole Depth Color: White Principal Uses: Pyroxylin (12% N), blasting explosives; pyrocellulose (12.60% N), smokeless powder; guncotton (13.35% N minimum), propellants
Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib	Color: White Principal Uses: Pyroxylin (12% N), blasting explosives; pyrocellulose (12.60% N), smokeless powder; guncotton (13.35% N minimum), propellants
For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib	Principal Uses: Pyroxylin (12% N), blasting explosives; pyrocellulose (12.60% N), smokeless powder; guncotton (13.35% N minimum), propellants
Total No. of Fragments: For TNT For Subject HE	Method of Loading:
	Loading Density: gm/cc
ragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Wet (8% to 30% water)
last (Relative to TNT):	Hazard Class (Quantity-Distance) Class 12
Air: Peak Pressure Impulse	Compatibility Group Group M (wet) Exudation None
Energy	Heat of:
Air, Confined: Impulse Under Water:	Combustion, cal/gm 2409* 2313** 2228*** Explosion, cal/gm 855* 965** 1058*** Gas Volume, cc/gm 919* 883** 853*** Formation cal/gm 617* 561** 513***
Peak Pressure	* 12.6% N
Energy	** 13.45% N *** 14.14% N
Underground: Peak Pressure	Vapor Pressure:
Impulse	mm Mercury
Energy	25 0.00 60 0.00

Nitrocellulose (NC)

Solubility in Water, gm/100 gm, at:	12.6% N	13.45% N	14.0% N
25°C	Insoluble	Insoluble	Insoluble
60°C	Insoluble	Insoluble	Insoluble
n - Wederleine - Anne -			
Solubility, gm/100 gm, 25°C, in:			
Ether	Insoluble	Insoluble	Insoluble
Alcohol	Very slight- ly soluble	Practically insoluble	Insoluble
2:1-Ether:Alcohol	Soluble	Slightly soluble (6%-11%)	Practically insoluble (1 + %)
Acetone	Soluble	Soluble	Soluble
	7.00	1 00	
240-Hour Hydrolysis Test, % Nitric Acid	1.22	1.03	

Preparation of Nitrocellulose from Cotton Linters:

(Laboratory Procedure)

<u>Nitration:</u> Second cut cotton linters, previously dried to a moisture content of less than 0.5%, are nitrated by immersion in mixed acid under the following conditions:

Ratio of Mixed Acid to cotton 55 to 1

Composition of Mixed Acid (approximate)

a. for 12.6% N: H2SO4 63.5%, HNO3 21%, H2O 15.5%

b. for 13.4% N: H2SO4 68%, HNO3 22%, H2O 10.0%

Temperature of acid at the start

Time of nitration

24 minutes

34°C

During the nitration period the mixture is turned over occasionally to keep the acid homogeneous. The mixture is then filtered on a Buchner funnel with suction for about three minutes and then drowned rapidly with strong hand stirring in at least 50 volumes of cold water. After the nitrocellulose has settled, most of the water is decanted and fresh water added. The nitrocellulose-water mixture is boiled and the acidity adjusted to 0.25% to 0.50% as H_2SO_4 . The sour boil is continued for at least 24 hours for pyrocellulose and at least 40 hours for gun-cotton. Additional boiling with changes of water are made in accordance with the governing specification (JAN-N-244).

<u>Pulping:</u> The nitrocellulose is then pulped in a laboratory Holland-type paper beater. Enough sodium carbonate is added to keep the reaction faintly alkaline to phenolphthalein. Pulping is continued to the desired degree of fineness.

<u>Poaching:</u> After washing the nitrocellulose from the beater, the mixture is filtered and the product boiled for 4 hours with fresh water while stirring mechanically. From time to time a little sodium carbonate solution is added to maintain the mixture faintly alkaline to phenolphthalein. The water is decanted and the boiling continued. According to the specification, the total boiling treatment with poaching is as follows:

- 4 hours boiling with or without sodium carbonate
- 2 hours boiling without sodium carbonate
- 1 hour boiling without sodium carbonate
- 1 hour boiling without sodium carbonate.

Each boil is followed by settling and change of water.

<u>Washing:</u> The nitrocellulose is then washed by mechanical agitation with water. A minimum of two washes are given. If a sample taken after the water washes gives a minimum test of 35 minutes in the 65.5°C Heat Test and 30 minutes in the 134.5°C Heat Test, the nitrocellulose is satisfactorily stabilized. Otherwise additional washes should be given.

Origin:

Cellulose occurs in nature. It is wood fiber, cell wall and the structural material of all plants. Cotton fiber is pure cellulose. Nitrocellulose was discovered about 1847 by C. F. Schonbein at Basel and R. Bottger at Frankfort-on-the-Main independently of each other when cotton was nitrated. T. J. Pelouze had nitrated paper earlier (1838) and was probably the first to prepare nitrocellulose.

Pyroxylin or collodion, which is soluble in a mixture of ether and ethanol, contains from 8% to 12% nitrogen. It is used in the manufacture of celluloid and in composite blasting explosives.

<u>Pyrocellulose</u>, a type of nitrocellulose of 12.6% nitrogen content, completely soluble in a mixture of 2 parts ether and one part ethanol, was developed by Mendeleev (1891-1895). This material, when colloided, formed the first smokeless powder for military use in the United States (1898).

<u>Guncotton</u> for military purposes today contains a minimum of 13.35% nitrogen. It is only slightly soluble in ether-ethanol, but completely soluble in acetone. Principal use is in flashless powders and as flame carriers. 14.14% N nitrocellulose represents a theoretical limit.

In the manufacture of propellants, there is used a mixture of pyrocellulose and guncotton (blended nitrocellulose) of 13.15% to 13.25% nitrogen content.

Destruction by Chemical Decomposition:

Nitrocellulose is decomposed by adding it, with stirring, to 5 times its weight of 10% sodium hydroxide heated to 70°C. Stirring is continued for 15 minutes after all the nitro-cellulose has been added.

References: 47

(a) See the following Picatinny Arsenal Technical Reports on Nitrocellulose:

47See footnote 1, page 10.

Nitrocellulose (NC)

<u>o</u>	<u>1</u>	2	<u>3</u>	<u>1</u>	5	6	<u>7</u>	8	<u>9</u>
10 390 420 660 730 960 1020 1100 1150 1210 1240 1300 1320 1320 1320 1410 1430 1490 1580 1660 1810 1830 1990 2210	41 101 231 351 831 851 1031 1041 1071 1201 1221 1331 1351 1391 1401 1541 1541 1681 1781 1831 1841 1851 1961 1961 2071 2181 2201	72 332 402 422 542 572 652 652 752 802 952 1012 1032 1142 1242 1362 1392 1642 1852 1912 1992 2022 2102	13 33 43 133 253 273 653 673 683 773 963 1023 1233 1273 1443 1663 1753 1813 1863 1873 1973	4 24 114 174 194 374 394 724 804 1054 1054 1054 1074 1084 1274 1304 1314 1394 1394 1454 16744 18244 18244 18244	125 475 485 495 555 705 965 1065 1125 1265 1265 1275 1365 1375 1745 1375 1845 1905 1915 1955	86 576 586 796 916 1026 1206 1206 1256 1306 1516 1516 1556 1616 1786 2056	167 327 407 717 787 987 1187 1297 1297 1297 1427 1447 1487 1587 1637 1717 1817 1827 1847 2137	8 198 208 278 388 408 588 718 758 778 808 838 1058 1228 1248 1348 1398 1478 1528 1638 1678 1838 1898 1918 2098 2208	19 29 69 169 279 499 669 709 779 809 909 1159 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1239 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1349 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 1329 13

Composition:	Molecular Weight: (C ₃ H ₅ N ₃ 0 ₉) 227
$^{\%}$ C 15.9 H_2 C $-$ ONO ₂	Oxygen Balance: 3.5 CO ₂ % 24.5
H 2.2 $HC - ONO_2$	Density: gm/cc 25°C, Liquid 1.591 20°C, Liquid 1.596
$H_2 C - ONO_2$	Melting Point: °C Labile form 2.2 Stable form 13.2
C/H Ratio 0.109	Freezing Point: °C
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C Decomposes 145
Sample Wt 20 mg	Refractive Index, n ^D ₂₀ 1.4732
Sample Wt, mg	n ₂₅ 1.4713 n ₃₀
Friction Pendulum Test: Steel Shoe Explodes Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C cc/gm/6 hrs 1.6 100°C ca/gm/16 hrs 11+
Rifle Bullet Impact Test: Trials	120°C
Explosions 100	135°C 150°C
Burned 0	200 Gram Bomb Sand Test:
Unaffected 0	Sand, gm Liquid method 51.5
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Explodes 222 10	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl
20	Ballistic Mortar, % TNT: (a) 140
	Trauzi Test, % TNT: (b) 181
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method
100°C Heat Test:	Condition
% Loss, 1st 48 Hrs 3.6	Contined
% Loss, 2nd 48 Hrs 3.5	Brisance % TNT
Explosion in 100 Hrs None	
Flammability Index:	- Detonation Rate: Confinement Glass Steel - Condition Liquid Liquid
Hygroscopicity: % 30°C, 90% RH 0.06	Charge Diameter, in. 0.39 1.25 Density am/cc 1.6 1.6
Volatility: 60°C, mg/cm ² /hr 0.11	Rate, meters/second 1600-1900 7700

Booster Sensitivity Test: Condition	nighere salabalaga	Decomposition Equation: Oxygen, atoms/sec 10	17.3 10 ^{19.2}
Tetryl, gm		(Z/sec)	
Wax, in. for 50% Detonation		(AH kcal/mol)	4 45.0
Wax, gm		Temperature Range, °C 90-1	35 125-150
Density, gm/cc		Phase Liqui	d Liquid
Heat of:	2626	Armor Plate Impact Test:	
Evaluation, cal/gm	1610		
Explosion, cal/gm	715	60 mm Mortar Projectile:	
Gas volume, cc/gm	110	50% Inert, Velocity, ft/sec	
Formation, cal/gm	400	Aluminum Fineness	
Fusion, col/gm Detonation, cal/gm	1486	500-1b General Purpose Bombs:	
Specific Heat: cal/gm/°C	THE CONTRACT OF A DAMAGE		
Liquid	0.356	Plate Thickness, inches	
mdara	0.30	A STATE OF STATE	
Solid	0.315	1	
	()sa - 27 00 7	11/4	
	1/201	$11/_{2}$	
	11112	13⁄4	
Burning Rate:	0/0/E		
cm/sec	Contractor Contractor Contractor	Bomb Drop Test:	
Thermal Conductivity:	i basi	T7, 2000-Ib Semi-Armor-Piercing	Bomb vs Concrete:
	Street in the local states		
Coefficient of Expansion:	a parti di contratta da	Max Safe Drop, ft	
Linear, %/°C	Adgenie z Inici Lacerty die	500-lb General Purpose Bomb vs	Concrete:
Volume, %/°C	iyo ni T	Height, ft	
	and the second second second	Trials	
Hardness, Mohs' Scale:	a i ha i ha an ar baar ar	Unaffected	
N	ti de recit destact	Low Order	
Toung's Modulus:	PLAT DESK NUMP	High Order	
E, dynes/cm ²	and works?		
E, Ib/inch ²	Constitution -	1000-Ib General Purpose Bomb vs	Concrete:
Density, gm/cc	Conductor 1		
Companying Street at 15 72 - 1.9	Seturiar of Malenda	Height, ft	
Compressive Strength: Ib/inch ²	WT A LONGER A	Trials	
หรือเสียนน้ำแหน่งสามารถกระบบการและและการการการการการการการก		Unaffected	
Vapor Pressure:	Duirolabletan Elifant	Low Order	
C mm Mercury C	mm Mercury	High Order	
0 0.00025 60 0 0.00083 70 0 0.0024 80 0 0.0073 90	0.0188 0.043 0.098 0.23		na se anajse ne i

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ragmentation Test:	Shaped Charge Effectiveness, TNT = 100:				
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb	Glass Cones Steel Cones Hole Volume Hole Depth				
Total No. of Fragments: For TNT	Color: Colorless				
For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib	Principal Uses: Propellant ingredient, demoli- tion explosive ingredient, grenade burster ingredient				
Total No. of Fragments: For TNT For Subject HE	Method of Loading:				
	Loading Density: gm/cc				
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method With acetone or other desensitized				
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy	Hazard Class (Quantity-Distance) Class 9 Compatibility Group Exudation				
Air, Confined: Impulse	Heat of Transition, cal/gm: Transition:				
Under Water: Peak Pressure	Liquid \rightarrow labile5.2Labile \rightarrow stable28.0Liquid \rightarrow stable33.2				
Impulse	Hydrolysis, % Acid:				
Underground:	10 days at 22°C <0.002 5 days at 60°C 0.005				
Peak Pressure	82.1°C KI Test:				
Energy	Minutes 10+				

Gas Evolved	at Atmospheric Pres	ssure, cc:			
Sample Wt Temperatu Time, hou Volume of	,gm 1. re, ^o C 65 rs 20 gas,cc nil	.6 75 40 nil			
Viscosity: (c)				
°C	Centipoises				
10 20 30 40 50 60	69.2 36.0 21.0 13.6 9.4 6.8				
Fragmentation	n Test:				
20 mm HE, of Fragmen	Mark 1, Projectile nts for:	e, Total No.			and and
Nitrog Tetran	Lycerin itromethane	22 17			
Minimum Prope	agating Diameter: (a)			
% Dimethyl in NO	Lphthalate	Min. Propagating Diameter, inches	<u>Maxim</u> 2 Tr	um Diameter : Failures in ials, inches	for The Constant of the set
0 5 10 15 20 22.5 25		(3/16 Cairns) 1/8 1/4 3/4 1 1.55		1/16 1/8 3/16 3/8 7/8 1-1/2 2	
<u>Sensitivity</u> t r	o Electrostatic Di no value given for	scharge, Joules (test confinement):	t condition, u	nconfined; > 12.5	
Solubility, g	rams of nitroglyce	rin/100 gm (%) of:			
Water	Alcohol	Trichlor	rethylene	Carbon Te	etrachloride
<u>°c</u> 2	<u>°c</u> ½	°C	%	°C	2
15 0.1 20 0.1 50 0.2	.6 0 37 .8 20 54 25	•5 Rm •0	22	Rm	2

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Carbon Disulfide

%

1

Soluble in all Proportions in:

<u>OC</u> Ambient

gm/100 gm (%), at 25°C in

Ether [∞] 2:1,Ether:Alcohol > 100 Acetone [∞]

Methanol Acetone Ether Ethyl acetate Amyl acetate Methyl nitrate Ethyl nitrate Nitroglycol Tetranitrodiglycerine Acetic acid Benzene Toluene Phenol Pyridine Xylene Nitrobenzene p-Nitrotoluene Liquid DNT Chloroform Ethyl chloride Ethyl bromide Tetrachloroethylene Dichloroethylene Trimethyleneglycol Dinitrate

Solubility in NG, of:

Alc	ohol	D	NT	T	NT	Wa	ter
°C	%	°C	70	°C	%	°C	%
0 20	3.4 5.4	20	35	20	30	25	0.06
50	00						

Preparation:

$$\begin{array}{c} CH_2 \longrightarrow OH \\ | \\ CH \longrightarrow OH \\ CH_2 \longrightarrow OH \end{array} + 3HNO_3 \longrightarrow \begin{array}{c} CH_2 \longrightarrow ONO_2 \\ | \\ CH \longrightarrow ONO_2 \\ CH \longrightarrow ONO_2 \\ CH \longrightarrow ONO_2 \\ | \\ CH_2 \longrightarrow ONO_2 \end{array} + 3H_2O$$

Glycerine is usually nitrated at 25° C, or below, by adding it very slowly to a well agitated mixture of nitric and sulfuric acids, e.g., 40/59.5/0.5, nitric acid/sulfuric acid/water, using an acid/glycerine ratio of approximately 6. Agitation of the reaction mixture is accomplished by use of compressed air. A rapid temperature rise, or appearance of red fumes, automatically requires dumping of the charge, immediately, into a drowning vessel filled with water. After all the glycerine has been added to the nitrator, agitation and cooling are continued until the temperature drops to about 15° C, and the charge is then run into a separator where the NG rises to the top, and is run off to the neutralizer. The nitroglycerin is washed first with water, then with sodium carbonate, and finally with water. The resultant NG when washed with water, produces washings which do not color phenolphthalein, and itself is neutral to litmus paper.

Origin:

Nitroglycerin was first prepared in 1846 or 1847 by Ascanio Sobrero, an Italian chemist (Mem Acad Torino (2) 10, 195 (1847)). For several years after this discovery, nitroglycerin attracted little interest as an explosive until Alfred Nobel in 1864 patented improvements in its manufacture and method of initiation (British Patent 1813). Nobel gave the name dynamite to mixtures of nitroglycerin and non-explosive absorbents, such as charcoal, siliceous earth or Kieselguhr (British Patent 1345 (1867)). Later developments led to gelatine dynamites, ammonia dynamites, and so called straight dynamites. The first propellants using nitroglycerin were called Ballistite (Nobel, British Patent 1471 (1888)) and Cordite (Abel and Dewar, British Patents <u>5614</u> and <u>11,664</u> (1889)).

Destruction by Chemical Decomposition:

Nitroglycerin is decomposed by adding it slowly to 10 times its weight of 18% sodium sulfide (Na₂S·9H₂O). Heat is liberated by this reaction; but this is not hazardous if stirring is maintained during the addition of nitroglycerin and continued until solution is complete.

References: 48

(a) A. H. Blatt, <u>Compilation of Data on Organic Explosives</u>, OSRD Report No. 2014, 29 February 1944.

- (b) Ph. Naoum, Z ges Schiess-Sprengstoffw, pp. 181, 229, 267 (27 June 1932).
- (c) Landolt Bornstein, Physikalisch-Chemische Tabellen, 5th Ed. (1923).

International Critical Tables.

B. T. Fedoroff et al, A Manual for Explosive Laboratories, Vol I-IV, Lefax Society, Inc., Philadelphia, 1943, 1946.

(d) H. A. Strecker, Initiation, Propagation and Luminosity Studies of Liquid Explosives, OSRD Report No. 5609, 3 December 1945.

(e) Also see the following Picatinny Arsenal Technical Reports on Nitroglycerin:

<u>o</u>	<u>1</u>	2	<u>3</u>	<u>1</u>	5	6	7	8	2
620 660 800 1020 1150 1210 1410 1620 1680	511 551 701 891 911 1031 1041 1151 1151 1221 1611 1651 1691	652 672 792 922 1142 1362 1542 1662 1692 1742 1752 1992	233 343 673 903 1023 1443 1643 1863 1863 1993	454 494 1024 1074 1084 1454 1524 1624 1674 1754	1155 1235 1955 2015	1206 1456 1496 1556 1616 1786 1816 1896 2056	817 837 1197 1297 1637 1817 1847	768 1348 1398 1738 1918 2098	69 249 709 1349 1359 2119

48See footnote 1, page 10.

Nitroguanidine

Composition:	Molecular Weight: $(CH_4N_4O_2)$	104
$C 11.5 \qquad NH_2$ H $3.9 \qquad HN = C$	Oxygen Balance: CO ₂ % CO %	-31 -15.4
N 53.8 NH	Density: gm/cc Crystal	1.72
0 30.8 ^{NO} 2	Melting Point: °C	232
C/H Ratio 0.038	Freezing Point: °C	apar at 197
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 26 Sample Wt, mg 7	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	
Friction Pendulum Test:(e)Steel ShoeUnaffectedFiber ShoeUnaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C	Ter English referies set
Rifle Bullet Impact Test: 5 Trials (e) Kapping Constraints (e) Restricts 0	- 100°C 120°C 135°C 150°C	0.37 0.44
Burned 0 Unaffected 100	200 Gram Bomb Sand Test: Sand, gm	36.0
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 275 10	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	0.20 0.10
15 20	Ballistic Mortar, % TNT: (a)	104
N-9 20 00L	Trauzi Test, % TNT: (b)	101
75°C International Heat Test:% Loss in 48 Hrs0.04	Plate Dent Test: (c) Method	A
100°C Heat Test: % Loss, 1st 48 Hrs 0.18 % Loss, 2nd 48 Hrs 0.09 Explosion in 100 Hrs None	Condition Confined Density, gm/cc Brisance, % TNT	Pressed No 1.50 95
Flammability Index:	- Detonation Rate: (e) Confinement	dina di second
Hygroscopicity: % 30°C, 90% RH None	Charge Diameter, in.	1.55
Volatility: None	Rate, meters/second	7650

Nitroguanidine

Fragmentation Test:	Shaped Charge Effectiveness, TNT $=$ 100:
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Cones Hole Volume Hole Depth
Total No. of Fragments: For TNT	Color: Colorless
For Subject HE	Principal Uses:
3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib	Propellant composition ingredient, bursting charge ingredient
Total No. of Fragments:	Method of Loading:
For TNT	(m) is a sharply series off
For Subject HE	Loading Density: gm/cc
Fragment Velocity: ft/sec At 9 ft At 25½ ft	Storage:
Density, gm/cc	Method Dry
Blast (Relative to TNT):	Hazard Class (Quantity-Distance) Class 9
Air: Peak Pressure	Compatibility Group Group I Exudation
Energy	
Air, Confined: Impulse	Solubility, gm/100 gm (%), in: OC % Water 25 0.44 100 9.0
Under Water: Peak Pressure Impulse	1.0 N Potassium 25 1.2 Hydroxide 25 1.2 40% Sulfuric Acid 0 3.4* 25 8.0*
Energy of the second	* gm/100 cc solution
Underground: Peak Pressure Impulse	Doos ter Densitivity lest.(d)ConditionPressedTetryl, gm100Wax, in. for 50% Detonation0.67Density, gm/cc1.41
cnergy protocological and a subscription of a	Heat of:
e seninden Derektionen och Derektionen och	Combustion, cal/gm1995Explosion, cal/gm721Gas Volume, cc/gm1077Formation, cal/gm227
Shald ≜dhist p∎kare prot	

Preparation:

(Chemistry of Powder and Explosives, Davis)



Four hundred gms of dry guanidine nitrate is added in small portions to 500 cc concentrated sulfuric acid at 10° C, or below. As soon as all crystals have disappeared the milky solution is poured into 3 liters of ice-water, and allowed to stand until crystallization is complete. The product is filtered, rinsed with water, and recrystallized from about 4 liters of boiling water, yield about 90%.

Origin:

Nitroguanidine was first prepared in 1877 by Jousselin, but it was 1900 before it found use in propellant compositions. During World War I, nitroguanidine was used by the Germans as an ingredient of bursting charge explosives.

Destruction by Chemical Decomposition:

Nitroguanidine is decomposed by dissolving in 15 times its weight of 45% sulfuric acid at room temperature and warming the solution until gas is evolved. Heating is continued for one-half hour.

References: 49

(a) L. C. Smith and E. G. Eyster, <u>Physical Testing of Explosives</u>, Part III - <u>Miscellaneous</u> Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) Canadian Report, CE-12, 1 May-15 August 1941.

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(e) Departments of the Army and the Air Force TM 9-1910/TO 11A-1-34, Military Explosives, April 1955.

⁴⁹See footnote 1, page 10.

(f)	Also see	the	following	Picatinny	Arsenal	Technical	Reports	on	Nitroguani	idine:	
	0		1	2	3	6	7		8	9	

	-		_				
1490	1391 2181 2201	1282 1392 2142	1183 1423 2193	1336	907 2177	758	1439 1749

Nitroisobutylglycerol Trinitrate (NIBTN) Liquid

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Composition:	Molecular Weight: $(C_{4}H_{6}N_{4}O_{11})$	286
c 16.8 $o_2 NO - CH_2$ H 2.1 $O_2 NO - CH_2$	Oxygen Balance: CO ₂ % CO%	0.0 22
N 19.6 $0_2^{NO-CH_2} - 0_2^{C-NO_2}$	Density: gm/cc 20 ⁰ C	1.64
0 61.5 02NO-CH2	Melting Point: °C	in the first
C/H Ratio 0.126	Freezing Point: °C	- 39
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus cm 25	Boiling Point: °C	internet in the second seco
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ³⁰	1.4896 1.4874
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C	a in all sol
Rifle Bullet Impact Test: Trials % Explosions	- 100°C 120°C 135°C 150°C	
Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm 0.2 gm sample absorbed by 0.2 gm of kleselguhr	1 ₂₈
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 185 10	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	Aig Paulo Pauso - Paulo Pauso - Venjevilat Concego
20	Ballistic Mortar, % TNT:	BankHone T. Mark
en Arrend a militaria en espera consider asque,	Trauzl Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method	nan in the
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:	- Detonation Rate: Confinement Glas	ss (1 mm wall)
Hygroscopicity: %	Charge Diameter, in.	0.39
Volatility: 25°C, mg/cm ² /24 hrs 0.127 x 10 ⁻³	Density, gm/cc Rate, meters/second	1.64 7860

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90 mm HE, M71 Projectil	e, Lot WC-91:	Glass Cones Steel (Cones
Density am/cc	- CO	Hole Volume	
Charge Wt lb		Hole Depth	
Charge Wt, ib			
Total No. of Fragments	i contra patriola	Color: Yel	low oil
For TNT		Andread and a second	
For Subject HE			
3 inch HE MA2A1 Project	tile. Lot KC-5:	Principal Uses: Gelatinizing age nitrocellulose	ent Ior
Density and /an	the salet selesatet		
Density, gm/cc		1 1 4 1 200 W	
Charge Wt, Ib			
lotal No. of Fragments:		Method of Loading:	
For TNT			
For Subject HE		Loading Density: gm/cc	Piter Street
Fragment Velocity: ft/sec	2.69	an a	
At 9 ft			
At 251/2 ft		Storage:	
Density, gm/cc			
		Method	Liquid
	THE FEADS ALIGN BRIDES OFF.		
		Hazard Class (Quantity Distance)	
Blast (Relative to TNT):		Hazard Class (Quantity-Distance)	
Blast (Relative to TNT):		Hazard Class (Quantity-Distance)	
Blast (Relative to TNT):		Hazard Class (Quantity-Distance) Compatibility Group	
Blast (Relative to TNT): Air: Peak Pressure		Hazard Class (Quantity-Distance) Compatibility Group Exudation	
Blast (Relative to TNT): Air: Peak Pressure Impulse		Hazard Class (Quantity-Distance) Compatibility Group Exudation	
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy		Hazard Class (Quantity-Distance) Compatibility Group Exudation	popper (general meneral en spriveren "Emprison "Emprison Suberenter, "O" 1
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy		Hazard Class (Quantity-Distance) Compatibility Group Exudation <u>Solubility:</u>	polytical ((1000 m)
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse		Hazard Class (Quantity-Distance) Compatibility Group Exudation <u>Solubility:</u> Solubility and ethyl	alcohols, ace
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse		Hazard Class (Quantity-Distance) Compatibility Group Exudation <u>Solubility:</u> Soluble in methyl and ethyl tone, ether, ethylenedichloride	alcohols, ace
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water:		Hazard Class (Quantity-Distance) Compatibility Group Exudation <u>Solubility:</u> Soluble in methyl and ethyl tone, ether, ethylenedichloride and benzene.	alcohols, ace-
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure		Hazard Class (Quantity-Distance) Compatibility Group Exudation Solubility: Soluble in methyl and ethyl tone, ether, ethylenedichloride and benzene.	alcohols, ace- e, chloroform
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse		Hazard Class (Quantity-Distance) Compatibility Group Exudation Solubility: Soluble in methyl and ethyl tone, ether, ethylenedichloride and benzene. Insoluble in water, carbon d and petroleum ether.	alcohols, ace- e, chloroform disulphide,
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy		Hazard Class (Quantity-Distance) Compatibility Group Exudation Solubility: Soluble in methyl and ethyl tone, ether, ethylenedichloride and benzene. Insoluble in water, carbon of and petroleum ether. Toricity:	alcohols, ace- e, chloroform disulphide,
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy		Hazard Class (Quantity-Distance) Compatibility Group Exudation Solubility: Soluble in methyl and ethyl tone, ether, ethylenedichloride and benzene. Insoluble in water, carbon d and petroleum ether. <u>Toxicity:</u>	alcohols, ace- e, chloroform disulphide,
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground:		Hazard Class (Quantity-Distance) Compatibility Group Exudation Solubility: Soluble in methyl and ethyl tone, ether, ethylenedichloride and benzene. Insoluble in water, carbon of and petroleum ether. <u>Toxicity:</u> Slight, decidedly less than	alcohols, ace- e, chloroform disulphide, nitroglycerin.
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure		Hazard Class (Quantity-Distance) Compatibility Group Exudation Solubility: Soluble in methyl and ethyl tone, ether, ethylenedichloride and benzene. Insoluble in water, carbon of and petroleum ether. <u>Toxicity:</u> Slight, decidedly less than Gelatinizing Action:	alcohols, ace- e, chloroform disulphide, nitroglycerin.
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse		Hazard Class (Quantity-Distance) Compatibility Group Exudation Solubility: Soluble in methyl and ethyl tone, ether, ethylenedichloride and benzene. Insoluble in water, carbon d and petroleum ether. <u>Toxicity:</u> Slight, decidedly less than <u>Gelatinizing Action:</u> Slight on nitrocellulose.	alcohols, ace- e, chloroform disulphide, nitroglycerin.
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy		Hazard Class (Quantity-Distance) Compatibility Group Exudation Solubility: Soluble in methyl and ethyl tone, ether, ethylenedichloride and benzene. Insoluble in water, carbon of and petroleum ether. <u>Toxicity:</u> Slight, decidedly less than <u>Gelatinizing Action:</u> Slight on nitrocellulose.	alcohols, ace- e, chloroform disulphide, nitroglycerin.
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy		Hazard Class (Quantity-Distance) Compatibility Group Exudation Solubility: Soluble in methyl and ethyl tone, ether, ethylenedichloride and benzene. Insoluble in water, carbon of and petroleum ether. <u>Toxicity:</u> Slight, decidedly less than <u>Gelatinizing Action:</u> Slight on nitrocellulose. 82.2°C KI Test:	alcohols, ace- e, chloroform disulphide, nitroglycerin.
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy		Hazard Class (Quantity-Distance) Compatibility Group Exudation Solubility: Soluble in methyl and ethyl tone, ether, ethylenedichloride and benzene. Insoluble in water, carbon of and petroleum ether. <u>Toxicity:</u> Slight, decidedly less than <u>Gelatinizing Action:</u> Slight on nitrocellulose. <u>82.2°C KI Test:</u> Minutes	alcohols, ace- e, chloroform disulphide, nitroglycerin.
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy		Hazard Class (Quantity-Distance) Compatibility Group Exudation Solubility: Soluble in methyl and ethyl tone, ether, ethylenedichloride and benzene. Insoluble in water, carbon of and petroleum ether. <u>Toxicity:</u> Slight, decidedly less than <u>Gelatinizing Action:</u> Slight on nitrocellulose. <u>82.2°C KI Test:</u> Minutes	alcohols, ace- e, chloroform disulphide, nitroglycerin.
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy		Hazard Class (Quantity-Distance) Compatibility Group Exudation Solubility: Soluble in methyl and ethyl tone, ether, ethylenedichloride and benzene. Insoluble in water, carbon of and petroleum ether. <u>Toxicity:</u> Slight, decidedly less than <u>Gelatinizing Action:</u> Slight on nitrocellulose. 82.2°C KI Test: Minutes	alcohols, ace- e, chloroform disulphide, nitroglycerin. 2

Preparation:

A total of 675 gm 37% formalin is added to 150 gm nitromethane containing 2 gm potassium carbonate hemi-hydrate. The first 200 gm formalin is added slowly, keeping the temperature below 30° C, and then the heat of reaction is allowed to raise the temperature to 80° C, and the mixture then heated two hours at 90° C. The reaction mixture is then concentrated at reduced pressure and diluted, and this process repeated several times to remove formaldehyde. After the final concentration the cooled mixture is filtered and the crystalline product recrystallized from alcohol and then several times from ether and dried.

The nitrated product is then obtained by nitrating 50 gm nitroisobutylglycerol with 300 gm mixed acid (60/38/2, sulfuric acid/nitric acid/water) below 15°C for 1.5 hours.

Origin:

This explosive (also called Trimethylolnitromethane Trinitrate, Nitroisobutanetriol Trinitrate, Nitroisobutylglycerin Trinitrate and incorrectly but widely used Nitroisobutylglycerol Trinitrate) was first described in 1912 by Hofwimmer (Z ges Schiess - Sprengstoffw 7, 43 (1912). Hofwimmer prepared the compound by the condensation of 3 moles of formaldehyde with 1 mole of nitromethane in the presence of potassium bicarbonate, the subsequent nitration of the product. The explosive can now be produced from coke, air, and natural gas.

References: 50

(a) H. A. Aaronson, Study of Explosives Derived from Nitroparaffins, PATR No. 1125, 24 October 1941.

(b) M. Aubry, Mém poudr, 25, 197-204 (1932-33); CA 27, 4083 (1933).

(c) A. Stettbacher, Nitrocellulose 5, 159-62, 181-4, 203-6 (1934); CA 29, 1250 (1935).

(d) W. de C. Crater, U.S. Patent 2,112,749 (March 1938); CA 32, 3964 (1938).

(e) H. J. Hibshman, E. H. Pierson, and H. B. Haas, Ind Eng Chem <u>32</u>, 427-9 (1940); CA <u>34</u>, 3235 (1940).

(f) A. Stettbacher, Z ges Schiess Sprengstoffw 37, 62-4 (1942); CA 38, 255 (1944).

⁵⁰See footnote 1, page 10.

AMCP 706-177

Nitrostarch Demolition Explosive (NSX)

Composition:		Molecular Weight:	325
% Nitrostarch (12.50% N) Barium Nitrate Mononitronaphthalene	49 40 7	Oxygen Balance: CO2 % CO %	-19 8
Paranitroaniline	3	Density: gm/cc	
Oil	1. 1. 1. 1	Melting Point: °C	and the set of the set
C/H Ratio		Freezing Point: °C	end tai mill 1 ditetti tankia
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	21	Boiling Point: °C	
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	8	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	
Friction Pendulum Test:	L'undradiid an 14	Vacuum Stability Test	281 385 1. 2011
Steel ShoeCrackleFiber ShoeUnaffect	s, snaps ted	cc/40 Hrs, at 90°C	
Rifle Bullet Impact Test: 10 Trials	8 Trials*	100°C	11+
Explosions 90	% 0	135°C 150°C	
Burned	10	200 Gram Bomb Sand Tast	
Unoffected 10 *Packed in paper	87	Sand, gm	39.5
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 195 10 15	in Barlin, Amhdal II 1. An Gàilte Ann an An Airtean 1. An Gàilte Ann an Airtean	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	0.26
20		Ballistic Mortar, % TNT: (a)	96
		Trauzl Test, % TNT:	
 75°C International Heat Test: % Loss in 48 Hrs 	0.2	Plate Dent Test: Method	ι,
100°C Heat Test:		Condition	
% Loss, 1st 48 Hrs	0.3	Confined	
% Loss, 2nd 48 Hrs	0.3	Density, gm/cc	
Explosion in 100 Hrs	None	Brisance, % TNT	
Flammability Index:		Detonation Rate: Confinement	
Hygroscopicity: % 30°C, 90% RH	2.1	Condition Charge Diameter, in.	
Volatility:		Density, gm/cc Rate, meters/second	

Nitrostarch Demolition Explosive (NSX)

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Fragmentation Test:	Shaped Charge Effectiveness, $TNT = 100$:
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Cones Hole Volume Hole Depth
Total No. of Fragments: For TNT	Color:
For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib	Principal Uses: Demolition, bursting charges, and priming compositions
Total No. of Fragments: For TNT	Method of Loading: Hand tamped
Fragment Velocity: ft/sec	Loading Density: gm/cc Apparent 0.92
At 9 ft At 25½ ft	Storage:
Density, gm/cc	Method Dry
Blast (Relative to TNT):	Hazard Class (Quantity-Distance) Class 9
Air: Peak Pressure	Compatibility Group Group I
Impulse Energy	Exudation None
Air, Confined: Impulse	120°C Heat Test: Salmon Pink 70 255
Under Water: Peak Pressure Impulse	Explodes 256
Energy	
Underground: Peak Pressure	
Impulse Energy	
	and present is a managerial weather the

Nitrostarch Demolition Explosive (NSX)

Preparation: (b)

The nitration of starch proceeds with the formation of hexanitro starch according to the following equation:

$2C_{6}H_{10}O_{5} + 6HNO_{3} \rightarrow C_{12}H_{14}O_{4}(ONO_{2})_{6} + 6H_{2}O_{6}$

Tapioca starch is considered the best for nitration purposes, although other starches give fairly stable products. The starch, pretreated to remove oils, fats and water soluble impurities, is dried and screened. Feeding of the dried starch into stainless steel nitrators containing mixed acid (62%-63% HNO₃ and 37%-38% H₂SO₄) is done slowly with constant agitation of the mixture. The heat evolved must be controlled by cooling coils. The nitrated starch is separated from the spent acid, washed with a large amount of water and centrifuged. Final drying is on trays heated to $35^{\circ}-40^{\circ}$ C with air. This product is so sensitive even a static discharge might cause explosion.

Nitrostarch demolition explosives contain a high percentage of nitrostarch, an oxidizing agent, mineral oil, a stabilizer and/or other ingredients.

Origin:

Nitrostarch was first prepared in 1833 by Branconnot, who called it xyloidine (Ann chim phys [2] 52, 290 (1833)). T. J. Pelouze studied xyloidine further and reported its explosive properties (Compt rend 7, 713 (1838). It found military use in the United States during World Wars I and II as blasting explosives and as an ingredient of bursting charges and priming compositions.

References: 51

(a) W. R. Tomlinson, Jr., Physical and Explosive Properties of Military Explosives, PATR No. 1372, 29 November 1943.

(b) G. D. Clift and B. T. Fedoroff, <u>A Manual for Explosives Laboratories</u>, Vol I, Lefax Society, Inc., Philadelphia (1942).

(c) Also see the following Picatinny Arsenal Technical Reports on Nitrostarch Explosives:

1	2	4	<u>7</u>	8	2
1611	782	1034	1117	838 848	1269

⁵¹See footnote 1, page 10.

Octol, 70/30

Composition:		Molecular Weight:	265
% HMX TUVT	70 30	Oxygen Balance: CO ₂ % CO %	- 38 -7•5
1111	<u> </u>	Density: gm/cc Cast	1.80
		Melting Point: °C	
C/H Ratio		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:	- 11 (1997) - 11 (1997)	Boiling Point: °C	outintal
Sample Wt 20 mg		Refractive Index, n ^D ₂₀	
Picatinny Arsenal Apparatus, in.	18	n ^D ₂₅	
Sample Wt, mg	20	n ^D ₃₀	
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	
Rifle Bullet Impact Test: Trials	. de la companya de la	- 100°C	
		120°C	0.37
Explosions		135°C	
Partials		150°C	i territerin territe
Burned		200 Gram Bomb Sand Test:	
Unaffected		Sand, gm Exploratory	58.4
Explosion Temperature:	°C	Sensitivity to Initiation:	he openddine fil
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm	
] 5 Flames erratically	225	Mercury Fulminate	
5 Flames effactically	222	Lead Azide	0.30
10		Tetryl	1111
20		Ballistic Mortar, % TNT:	115
	antrial Object	Trauzl Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs		Plate Dent Test: Method	ndonal (* .)
100°C Host Tost		Condition	
% Loss 1st 48 Hrs		Confined	
% Loss 2nd 48 Hrs		Density, gm/cc	
Explosion in 100 Hrs		Brisance, % TNT	
Flower killer la la		Detonation Rate:	
riammability Index:		Confinement	None
Hygroscopicity: %		- Condition	Cast
		Charge Diameter, in.	1.0
Volatility:		Density, gm/cc	1.00
		Kate, meters/second	03/7

Heat of:

cm/sec

Thermal Conductivity:

Coefficient of Expansion: Linear, %/°C

cal/sec/cm/°C

Volume, %/°C

Young's Modulus:

E', dynes/cm² E, Ib/inch²

Density, gm/cc

Vapor Pressure: °C

Compressive Strength: Ib/inch²

mm Mercury

Hardness, Mohs' Scale:

Booster Sensitivity Test: Decomposition Equation: Oxygen, atoms/sec Condition (Z/sec) Tetryl, gm Heat, kilocalorie/mole Wax, in. for 50% Detonation $(\Delta H, \text{kcal/mol})$ Temperature Range, °C Wax, gm Phase Density, gm/cc Armor Plate Impact Test: 2722 Combustion, cal/gm 1074 Explosion, cal/gm 60 mm Mortar Projectile: 847 Gas Volume, cc/gm 50% Inert, Velocity, ft/sec ----Aluminum Fineness Formation, cal/gm Fusion, cal/gm 500-Ib General Purpose Bombs: Specific Heat: cal/gm/°C Plate Thickness, inches 1 11/1 11/2 13/4 **Burning Rate:** Bomb Drop Test:

T7, 2000-Ib Semi-Armor-Piercing Bomb vs Concrete:

Max Safe Drop, ft

500-lb General Purpose Bomb vs Concrete:

Height, ft
Trials
Unaffected
Low Order
High Order

1000-Ib General Purpose Bomb vs Concrete:

Height, ft
Trials
Unaffected
Low Order
Hiah Order

Compressive Strength: 1b/inch ²	*	- Identification and I
Average (10 tests)	Ultimate Deformation: %	, and a second
High Low 13	Average (10 tests) High Low	2.26 2.58 1.97

*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

1510

See below

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Fragmentation Test:	Shaped Charge Effectiveness, TNT $=$ 100:
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Cones Hole Volume Hole Depth
Total No. of Fragments: For TNT	Color: Buff
For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib	Principal Uses: HE projectile and bomb filler
Total No. of Fragments: For TNT For Subject HE	Method of Loading: Cast
Fragment Velocity: ft/sec	Loading Density: gm/cc 1.80
At 9 ft At 25½ ft Density, gm/cc	Storage:
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy	Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation
Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure	Work to Produce Rupture:ft-lb/inch ³ *Average (10 tests)1.55High1.87Low1.10Efflux Viscosity, Saybolt Seconds:5.9
Impulse Energy	*Test specimen 1/2" x 1/2" cylinder (approxi- mately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

ć,

Octol, 70/30

		One-Inc	h Column	Two-Inc	h Column
Explosive	Simulated Altitude,	Confined	Unconfined	Confined	Unconfined
	Feet	m/s	m/s	m/s	m/s
70/30, RDX/INT; density, gm/cc 1.62	Ground	7900	8100	7660	8030
demotoy, Emperative	30,000	8020	8120	7900(4)	7800
	60,000	8040	8140	8010	7950
	90,000	8060	7980	8010	7710
Average		8005	8085	7895	7873
70/30, HMX/TNT;	Ground	7960	7900(4)	7870	7640(4)
density, gm/cc 1.01	30,000	8050	8060	7930	7710
	60,000	8020	7930	7890	7650
	90,000	7950	8000	7940	7650
Average	The other ext	7995	7973	7908	7663

Effect of Altitude, Charge Diameter and Degree of Confinement on Detonation Velocity* (Reference b)

*70/30 Octol confined charge in 1/4" steel tube, AISI 1015 seamless, 1" diameter 18" long, and 2" diameter 7" long. All means were determined from sets of five values unless otherwise indicated by (). A 26 gm tetry booster was used to initiate each charge.

Average Fragment Velocities at Various Altitudes*

(g)

			Simulated A	Ltitude, Fe	et
Explosive	Charge Diameter,	Ground m/s	30,000 m/s	60,000 m/s	90,000 m/s
70/30, RDX/INT	1	3415 4647	3672 5192	3666 5236	3685 6011
70/30, HMX/INT	1 2	3366 4703	3680 5464	4014 6089	3617 6111

*Outside diameter 2.54"; inside diameter 2.04"; length 7".

Octol, 70/30

Tensile Strength:*

-		lb/inch ²	
	Average (8 tests)	169	
	High	204	
	Low	128	

*Test specimen as per Picatinny Arsenal sketch XL-076B, at 21°C.

Modulus of Elasticity:*

Average (10 tests)	1b/inch ² 73,200
High	79,300
LOW	63,000

*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

Setback Sensitivity Test: (a)

Critical Pressure	92,000 psi*
Density, gm/cc	1.72

*Pressure below which no initiation is obtained and above which an increasing percentage of initiations can be expected as the setback pressure increases.

Pit Fragmentation Test:

105 mm Ml HE Projectile:

Weight Group, grains	No. of Fragments	inglasias Langaratana:
1/2 - 2	1297	three day of the day work
2 - 5	665	the state is the second
5 - 10	497	
10 - 25	661	20
25 - 50	471	Streaminent How Furt
50 - 75	247	with \$5 terminate and
75 - 150	322	90°C Beer Texes
150 - 750	295	Mr. Long, Ist AB Hits
750 - 2500	Tell Manager 12	Endokion in 1,00 Elei
Total Number	4467	
relativ	Contribution of	a stand of the standard of the
		fygreinapleityr (b

vulneilitev.

Composition:		Molecular Weight:	276
HMX	75	Oxygen Balance:) nga post
TNT	25	CO %	-35 -6.3
		Density: gm/cc Cast	1.81
		Melting Point: °C	in in the
C/H Ratio		Freezing Point: °C	De nieboli
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C	eggegrind.
Bureau of Mines Apparatus, cm Sample Wt 20 mg		Refractive Index, n ^D ₂₀	Tlak
Picatinny Arsenal Apparatus, in.	17	n D-	
Sample Wt, mg	25	n ₃₀	
Friction Pendulum Test:		Vacuum Stability Test:	i dinaka ka kara bi
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	
Rifle Bullet Impact Tests 10Trick		100°C	
3/16" Steel	1/8" Al	120°C	0.39
Explosions 70	70	135°C	
Partials		150°C	
Burned		200 Gram Bomb Sand Test:	1000123.4.53
Unoffected 30	30	Sand, gm Exploratory	62.1
Explosion Temperature:	°C	Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm	
1		Mercury Fulminate	
5 Flames erratically	350	Lead Azide	0.30
10		Tetryl	
15		Ballistic Mortar, % TNT:	116
		Trauzl Test, % TNT:	
75°C International Heat Test:		Plate Dent Test:	
% Loss in 46 Hrs		Method	
100°C Heat Test		Condition	
% Loss. 1st 48 Hrs		Confined	
% Loss, 2nd 48 Hrs		Density, gm/cc	
Explosion in 100 Hrs		Brisance, % TNT	
		Detonation Rate:	-At Japandi
Flammability Index:		Confinement	None
Hummer istra 0/		Condition	Cast
nygroscopicity: %		Charge Diameter, in.	1.0
Volatility		Density, gm/cc	1.81
volutility;		Rate, meters/second	8643

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Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH, kcal/mol) Temperature Range, °C Phase
Heat of: Combustion, cal/gm2676Explosion, cal/gm1131	Armor Plate Impact Test:
Gas Volume, cc/gm 830 Formation, cal/gm	50% Inert, Velocity, ft/sec Aluminum Fineness
*Calculated for 76.9% HMX, 23.1% TNT.	500-Ib General Purpose Bombs:
-79°C 0.200 -80° to +80°C 0.240 33° to 74°C 0.245 90° to 150°C 0.323 **Determined for 76.9% HMX, 23.1% TNT.	Plate Thickness, inches
Burning Rate: cm/sec	Bomb Drop Test:
Thermal Conductivity: cai/sec/cm/°C	T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:
Coefficient of Expansion: Linear, %/°C	Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete:
Volume, %/°C	Height, ft
Hardness, Mohs' Scale:	Unaffected
Young's Modulus: E', dynes/cm ²	High Order
E, lb/inch² Density, gm/cc	1000-lb General Purpose Bomb vs Concrete:
Compressive Strength: Ib/inch ² 1340 See below	Height, ft Trials Unaffected
Vapor Pressure: °C mm Mercury Compressive Strength: 1b/inch ² ***	Low Order High Order
Average (10 tests) 1340 High 1560 Low 1040	Ultimate Deformation: %Average (10 tests)2.43High2.89Low2.04

***Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

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Octol, 75/25

Fragmentation Test:		Shaped Charge Effectiveness, TNT = 100:	
90 mm HE, M71 Project	tile, Lot WC-91:	Glass Cones Steel Cones	
Density, gm/cc		Hole Volume	
Charge Wt, Ib		Hole Depth	
Total No. of Fragment	s:	Color:	Buff
For TNT			16.24
For Subject HE		Principal Uses: HE projectile and bom	filler
3 inch HE, M42A1 Proje	ctile, Lot KC-5:	1000 (1000 1000 1000 1000 1000 1000 100	na sangén Pangén
Density, gm/cc		1. SVE * 1	
Charge Wt, Ib		ning sh	
Total No. of Fragments:		Method of Loading:	Cost
For TNT		Collio	Cast
For Subject HE		G19 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	
		Loading Density: gm/cc	1.81
Fragment Velocity: ft/sec		こので 表示とう こうしょう しんかん	
At 9 ft At 25½ ft		Storage:	
Density, gm/cc		50	
		Method	Dry
Blast (Relative to TNT):	TT. 2000. b. Sami Amerika	Hazard Class (Quantity-Distance)	Class
· ·		Compatibility Group	Active Market
Air: Peok Pressure		Company Group	Group
Impulse		Exudation	
Energy			1 CIDMENT
		Manile to Decidence Denterrow St. 12 (in).	3
Air, Confined:		work to Produce Rupture: 1t-15/1nch-	
Impulse		Average (10 tests)	1.31
Under Water		High	1.57
Peak Pressure		LOW	1.07
Impulse		Efflux Viscosity, Saybolt Seconds:	9.0
Energy			
Underground:			
Peak Pressure		Oldi - Prischer Gyllen - Sterner	
Impulse		and a set of the set	
Energy			
		*Test specimen 1/2" x 1/2" cylinder (mately 3 gm) pressed at 3 tons (6.00	approxi 0 1b)
		total load or 30,000 psi with a 2 mi	nute
		time of dwell.	
		6.4o.r	

alarmalandalar itali a 1/1 " 1/1" and 1000 the too the second second second second second second second second s

Fragment Velocity Test:

M26 Hand Grenade:

Trolocive	Average Fragment Velocity,
Exprosive	
Composition B 75/25 Cyclotol	4948 4908
75/25 Octol	5124

Tensile Strength:*

	lb/inch ²
Average (10 tests)	266
High	330
Low	226

*Test specimen as per Picatinny Arsenal sketch XL-076B, at 21°C.

(a)

(a)

Modulus of Elasticity:*

			lb/inch ²
Average	(10	tests)	62,100
High			75,900
Low			45,200

*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

Se	tback a	Sens	sitivity	Test	:	(a)	
	Criti Densi	cal ty,	Pressure gm/cc		76,000 1.80	psi*	

*Pressure below which no initiation is obtained and above which an increasing percentage of initiations can be expected as the setback pressure increases.

Pit Fragmentation Test:

105 mm Ml HE Projectile:

Weight Group, grains	No. of Fragments
1/2 - 2	1611
2 - 5	777
5 - 10	535
10 - 25	719
25 - 50	480
50 - 75	246
75 - 150	339
150 - 750	293
750 - 2500	8
Total Number	5008

Preparation:

Water-wet HMX is added slowly to molten TNT in a steam-jacketed kettle at a temperature of 100° C. The mixture is heated and stirred until all moisture is evaporated. The composition is cooled to a satisfactory pouring temperature and cast directly into ammunition components or prepared in the form of chips to be stored for later use.

References: 52

(a) 1st Indorsement from Chief, Explosives Development Section, to Chief, Explosives Research Section, Picatinny Arsenal, dated 12 May 1958. Subject: "Properties of Octols and HTA-3."

(b) A. W. O'Brien, Jr., C. W. Plummer, R. P. Woodburn and V. Philipchuk, <u>Detonation Veloci-</u> ty Determinations and Fragment Velocity Determinations of Varied Explosive Systems and Conditions, National Northern Corporation Final Summary Report NNC-F-13, February 1958 (Contract DAT-19-020-501-ORD-(P)-58).

⁵²See footnote 1, page 10.

Composition:	Molecular Weight: 245
RDX 90	Oxygen Balance: -62 CO ₂ % -62 CO % -18
Dioctylphthalate 1.5	Density: gm/cc Unpressed 0.81 Pellet pressed at 30,000 psi 1.62
	Melting Point: °C
C/H Ratio	Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: <u>Unpressed</u> Bureau of Mines Apparatus, cm 28	Boiling Point: °C
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 15 Sample Wt, mg 20	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀
Friction Pendulum Test:	Vacuum Stability Test:
Steel ShoeUnaffectedFiber ShoeUnaffected	cc/40 Hrs, at 90°C
Rifle Bullet Impact Test: 10 Trials *	120°C 0.41
Explosions 10	135°C 150°C
Partials 90 Burned 0 Unaffected 0	200 Gram Bomb Sand Test: Sand, gm
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Smokes 275 10 15	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl Ballistic Mortar, % TNT:
20	Trouvel Lest % TNT:
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method
100°C Heat Test: 0.00 % Loss, 1st 48 Hrs 0.00 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None	Condition Confined Density, gm/cc Brisance, % TNT
Flammability Index:	- Detonation Rate: Confinement
Hygroscopicity: %	Condition Charge Diameter, in.
* Test procedure described in PATR No. 2247, May 1956.	Density, gm/cc Rate, meters/second

PB-RDX

Booster Sensitivity Test: Condition	Decomposition Equation: Oxygen, atoms/sec
Tetryl, gm	(Z/sec)
Wax, in. for 50% Detonation	Heat, kilocalorie/mole
Wax, am	Temperature Range, °C
Density am/cc	Phase
Heat of:	Armor Plate Impact Test:
Combustion, cal/gm 3027	C/H Rune
Explosion, cal/gm 903	60 mm Mortar Projectile:
Gas Volume, cc/gm	50% Inert, Velocity, ft/sec
Formation, cal/gm	Aluminum Fineness
Fusion, cal/gm	5 Community and the second se second second sec
	500-Ib General Purpose Bombs:
Specific Heat: cal/gm/°C	The second
	Plate Thickness, inches
	Strat Strat Strate
	Last with the second second second
	11/4
	1½
	134
Burning Rate:	in the second
cm/sec	Bomb Drop Test:
Thermal Conductivity:	Lippedi.
cal/sec/cm/°C	T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:
	Max Safe Drop ft
Coefficient of Expansion:	Max Sale Diop, it
Linear, %/°C	500-Ib General Purpose Bomb vs Concrete:
Volume, %/°C	Height ft
lag () and the second s	Triols
Hardness, Mohs' Scale:	lineffected
representation in the first of the latter of the spectrum states of a summarian structure state of the second states of the second stat	
Young's Modulus: See below	Low Order
E', dynes/cm ²	High Order
E. Ib/inch ²	1000 Ib Consul Burnass Barrh us Consults
Density am/cc	TOUD-ID General Purpose Bomb vs Concrete:
birden 5	Height ft
Compressive Strength: Ib/inch ² 2403 2149	Trials
Percent 8.9 13.1	Unoffected
Vapor Pressure:	Low Order
Vermale Meduluer * (c)	High Order and a filled assessed
roung's Modulus: * (a) Temperature	and the second sec
E, lb/inch ² (avg of 5) 39,953 34,831	01. 1.5.1. million (1.5.4)
Density, gm/cc 1.60 1.57	[14] Schulzer Statistical Statistics (11) Statistics and a structure of the supersystem of the Cold CD, while an Ability of the statistics of the statistics of the statistics of the Statistics of the statistics of the statistics of the statistics of the statistics of the Statistics of the statist

*Pellets (Lot OAC-596-55) 0.750 inch diameter by 0.750 inch long, pressed at 30,000 psi with 30-second dwell.

Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100:						
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones Steel Cones						
Density, gm/cc	Hole Volume						
Charge Wt, Ib	Hole Depth						
Total No. of Fragments:	Color: White						
For TNT	The second						
For Subject HE	Principal Uses: High mechanical strength						
3 inch HE, M42A1 Projectile, Lot KC-5:	exprosive						
Density, gm/cc							
Charge Wt, Ib							
Total No. of Fragments:	Method of Loading: Presse						
For TNT	and the second						
For Subject HE	Loading Density: gm/cc Pressed, psi x 10 ³						
Fragment Velocity: ft/sec	1.10 1.49 1.59 1.62						
At 9 ft At 25½ ft	Storage:						
Density, gm/cc	Method Dry						
Blast (Relative to TNT):	Hazard Class (Quantity-Distance) Class						
Air: Peak Pressure	Compatibility Group Group						
Impulse	Exudation						
Energy							
Air, Confined:	Rockwell Hardness, "R" Scale: (a) 1/2 inch diameter Penetrator, 60 Kg Load:						
Impulse	Pellet Specific						
Under Water: Peak Pressure	No.* Gravity Hardness						
Impulse	1 1.624 84						
Energy	2 1.623 $903 1.611 84$						
analy formation and shared was a start many fi	4 1.600 80						
Underground:	5 1.590 75						
Peak Pressure	6 1.571 73						
Impulse	8 1.524 49						
Energy							
	*Pellets (Lot HOL-E-93) were 1-1/2 inches in diameter and 3/4 inch high.						
Pellets* to) Initia	tion by	Type II	Special	Blasting	Caps	(a)
--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	-----------	----------	----------	----------	----------	-----------	--------------------------------
iona Copies - Internet Alexandre	Gap	(Distanc	e From B	ase of C	ap to Pe	llet), In	nches
Pellets	0.250	0.300	0.350	0.400	0.450	0.500	0.750
PB-RDX with Pellet Density 1.55 gm/cc							
	-	0					
No. of Trials	1	8	5	6	2	1	1
Average Depth of Plate							
Indentation, inches **	0.082	0.090	0.087	0.080	0.080		
				1			a la nd a jing dara
No. of Failures	0	l	3	4	1	1	1,
PB-RDX with Pellet Density		1. 					
	n na stàp						
No. of Trials	3	8	9	24	3	5	2
A file for a second of the second sec							
Indentation inches **	0.000	0.080	0.087	0.081	0.09.7	0.075	
indentiation, inches an	0.090	0.009	0.001	0.004	0.001	0.075	ATTAC V MARK
No. of Failures	0	0	2	3	2	3	2
98/2 RDX/Stearic Acid With Pellet Density 1.63 gm/cc	L a	riup/sk					and a chami
No. of Trials	- 5	3	5	5	5	5	⊳5 nation feitte da
Average Depth of Plate Indentation, inches **	0.109	0.096	0.095	0.092	0.097	0.087	
No of Foilumon	0	esta la	0		1		
NO. OI FAILURES	0	1	0	3	4	4	5

** Mild steel plate 5" x 5" x 1".

Performance of PB-RDX as Booster: (b, d)

Ten 2.75 inch HEAT ML Rocket Heads were unaffected in performance by storage at 71°C for 28 days. Thus, PB-RDX was not desensitized by contact with TNT-bearing explosives. Tetryl, similarly used, becomes desensitized when stored in bursting charges at elevated temperatures.

In addition, 108 modified M307Al 57 mm projectiles were fired for performance against armor. Each round contained a PB-RDX booster pellet. There was no evidence in these firings that the projectiles were inadequately boostered.

PB-RDX

PB-RDX

Preparation:

The purchase description sheet for polystyrene-bonded RDX (X-FA-PD-1088, 25 October 1956) requires that the PB-RDX shall be a mixture of RDX, coated and surrounded by a homogeneous mixture of polystyrene and dioctylphthalate. The specified percentage of RDX shall consist of a mixture of 75% Type B, Class A RDX and 25% Type B, Class E RDX. The granulation of the unpressed composition shall be as follows:

	Through U. S. Standard Sieve No.	Minimum %	Maximum %
T	6	100	
	12	60	
	20		2
	35		0

Two methods have been reported for the preparation of PB-RDX (Reference: Los Alamos Scientific Laboratory, Contract W-7405-Eng 36 with U.S. Atomic Energy Commission, Report No. IA-1448). The earlier method employed a Baker-Perkins type mixer to blend the components. This procedure gave a product with good pressing characteristics. However, the molding composition was nonuniform in granulation and tended to be dusty. The slurry method of PB-RDX preparation gave a product which was uniform, free-flowing and dustless. In addition, PB-RDX granulated by the slurry method exhibited satisfactory drying, handling and pressing characteristics.

The final procedure incorporating the better features found from the study of such variables as solvents, solvent/plastic ratios, lacquer addition and temperature, agitation, RDX particle size distribution, dispersants and rosin additive, was as follows (Reference c):

Forty-two and five-tenths grams (42.5 gm) of polystyrene and 8 cc dioctylphthalate were dissolved in 200 cc toluene in a lacquer dissolver. Steam was introduced into the jacket until the temperature reached 65°C. The lacquer was agitated constantly until it was ready to be added to the granulator. This lacquer contained a 1:4 ratio of plastic-plasticizer to toluene.

Four hundred and fifty grams (450 gm) of RDX and 4500 grams of H_2O (ratio 1:10) were added to the granulator. The agitator was set for 400 rpm and the temperature was raised to 75°C by introducing steam into the jacket. The temperature differential between the lacquer solution and the RDX/water slurry was 5° to 10°C.

The lacquer solution was poured through the charging funnel into the granulator. As soon as the lacquer was added, a solution of gelatin in water was added, and the mixture was agitated until the lacquer was well dispersed in the RDX slurry (approximately 5 minutes). Granulation took place at this point. Steam was introduced again into the jacket to distill the solvent until the temperature reached 98°C. Cooling water was then run into the jacket to cool the batch to 40°C. The coated material from the granulator was collected on a Buchner funnel and dried in a tray at 70°C for 24 hours. Temperatures below 70°C did not furnish enough heat, but a temperature of 80°C produced stickiness and caking of PB-RDX.

Origin:

An explosive consisting of RDX coated with polystyrene plasticized with dioctyphthalate was initially developed in 1952 for the Atomic Energy Commission by Los Alamos Scientific Laboratory of the University of California (Contract W-7405-Eng 36 with U. S. Atomic Energy Commission, Report No. LA-1448). The specific formulation of 90/8.5/1.5 RDX/polystyrene/ dioctylphthalate was subsequently standardized by Los Alamos. This explosive, originally designated PBX, has been redesignated PB-RDX. The detailed requirements for the present polystyrene-bonded RDX(PB-RDX) are given in purchase description X-PA-PD-1088, 25 October 1956.

References: 53

(a) B. J. Zlotucha, T. W. Stevens and C. E. Jacobson, <u>Characteristics of Polystyrene-</u> Bonded RDX(PB-RDX), PATR No. 2497, April 1958.

(b) A. J. Pascazio, The Suitability of a Bare PBX Booster Pellet in the 2.75 Inch M1 HEAT Rocket Head, PATR No. 2271, November 1955.

(c) J. L. Vermillion and R. C. Dubberly, <u>Plastic-Bonded RDX</u>, Its Preparation by the Slurry <u>Method</u>, Holston Defense Corporation, Control No. 20-T-16 Series A (PAC 1081), 5 March 1953.

(d) C. J. Eichinger, <u>Report on Cartridge HEAT 57 mm M307A1 (Mod) with Modified Copper</u> Liner, Aberdeen Proving Ground, Development and Proof Services, First Report on OC Project TA3-5204, October 1957.

⁵³See footnote 1, page 10.

Pentaerythritol Trinitrate (PETRIN)

Composition:	Molecular Weight: (C5H9N3010) 271
6 22.1 Н 3.3	Oxygen Balance: CO ₂ % -27 CO % 3
$\frac{\text{HOCH}_2 - \dot{c} - \text{CH}_2 \text{ONO}_2}{1 + 1 + 1 + 2 + 2 + 2 + 2 + 2 + 2 + 2 + $	Density: gm/cc 1.54
0 59.1 CH ₂ ONO ₂	Melting Point: °C 26 to 28
C/H Ratio 0.141	Freezing Point: °C
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C 4 mm Hg Decomposes 130
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 5 to 10 Sample Wt, mg 38	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀
Friction Pendulum Test:	Vacuum Stability Test:
Steel Shoe Fiber Shoe	cc/40 Hrs, at 90°C
Rifle Bullet Impact Test: Trials % Explosions Partials	
Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10 15	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl
20	Ballistic Mortar, % TNT:
75°C International Heat Test: % Loss in 48 Hrs	Trauzi Test, % TNT: Plate Dent Test: Method
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Condition Confined Density, gm/cc Brisance, % TNT
Flammability Index:	Detonation Rate: Confinement
Hygroscopicity: %	Condition Charge Diameter, in.
Volatility:	Density, gm/cc Rate, meters/second

Fragmentation Test:	w udusalast	Shaped Charge	Effectiveness,	TNT = 100:	rdition indi
90 mm HE, M71 Projectile, Lot WC-91:	Oregold, Below		Glass Cones	Steel Cones	
Density, gm/cc		Hole Volume			
Charge Wt. Ib		Hole Depth			
	and a state of the				
Total No. of Fragments:	and the second		1	and the second	
For TNT	· · · · · · · · · · · · · · · · · · ·	Color:			White
For Subject HE	Percent and and				
		Principal Uses:	Explosive,	propellant o	or
3 inch HE, M42A1 Projectile, Lot KC-5:	na Pathat		igniter in	gredient	
Density am/cc					
Charge Wt Ib	or and a colum-				
Charge Wit, ib					
Total No. of Fragments:					
For TNT		Method of Load	ling:		
For Subject UE	and addressing				
For Subject HE	1.11.12		,		
		Loading Density	sgm/cc		
Fragment Velocity: ft/sec	. 0.01				
At 9 ft	- 116 I	Storage			
	1416.1	storage.			
Density, gm/cc	1940 - C	Method			Drv
	and an end of the				
Blast (Relative to TNT):	ing prof	Hazard Class	Quantity-Dist	tance)	
Air: Peak Pressure	er sakatadad menunuki	Compatibility	Group		
Impulse	multi-	Exudation			None
Energy	- hogy				
	Sector 1	PETRIN es	sters are li	sted in refer	ence (b)
Air, Confined:	1 and 1 million of signature products	and most of	these ester	s have been s	hown to
Impulse	Balliette	have explosi	ve properti	es.	
Under Weber	Alter I learn't	An infrar	red spectrop	hotometric pr	ocedure
Peak Pressure	the set and	was develope	ed for the d	etermination	of the
	in a second s	acetone cont	ent of PETR	IN (ref c).	A 2.5 gm
Energy		sample of PE	STRIN 15 dis me increase	d to 25 milli	liters in
Energy		a volumetric	flask. Th	e acetone con	itent of
Underground	S II. I STORE	the PETRIN s	solution is	determined by	its infra
Peak Pressure	C. Sussess	red absorpti	on at 5.82,	. in a 0.5 mm	n cell. A
Impulse	Sources and the second second	double beam	method is u	sed with a re	ference
Energy	1 Au District and	PETRIN. The	aug calorol	orm and aceto f the latter	must be
Absolute Viscosity, poises:	Contribution of	carefully ad	justed to g	ive a good ba	lance be-
Temp 17 ⁰ C 1) 8		tween the te	est sample a	nd reference	cells for
23°C 4.8		the strong F	PETRIN peak	at 6.02, may	cimum.
28°C 3.0	a subscription of the	Hept of			
38°C 1.2	of a president	neat OI:			and States P
	stres abs0	Explosion	n, cal/gm		1204

Pentolite, 50/50; 10/90

AMCP 706-177

Booster Sensitivity Test:(d)50/50ConditionPressedCastTatada area100100	Decomposition Equation: Oxygen, atoms/sec
Wax, in. for 50% Detonation 2.36 2.08	Heat, kilocalorie/mole
Wax, gm	(ΔH, kcal/mol) Temperature Range, °C
Density, gm/cc 1.60 1.65	Phase
Heat of: Combustion, cal/gm Explosion, cal/gm 1220 Gas Volume, cc/gm Formation, cal/gm	Armor Plate Impact Test: 50/50 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec 170 Aluminum Fineness
Fusion, cal/gm	500-lb General Purpose Bombs:
Specific Heat: cal/gm/°C	Plate Thickness inches
	The fine fine field and the second seco
	1
	11/4 and still by Handrid V. Hearing and 3
	11/2
Burning Rate	13/4
cm/sec	for market strong of the
Thermal Conductivity: cal/sec/cm/°C	T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:
Coefficient of Expansion: Linear, %/°C	Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete:
Volume, %/°C	Height, ft
Manda and a second s	Trials
naraness, Mohs' Scale:	Unaffected
Young's Modulus:	Low Order
E', dynes/cm ²	High Order
E, lb/inch ²	unhagent
Density, gm/cc	1000-16 General Purpose Bomb vs Concrete:
Compressive Strength: Ib/inch ² 2000, 2000	Height, ft
Density, gm/cc 1.68	Trials
Vanas Proseuro	Unattected
°C mm Mercury	Low Urder High Order

Pentolite, 50/50; 10/90

Fragmentation Test:	50/50	Shaped Charge Effectiveness, TNT = 100: <u>50/50</u> 10/90 <u>50/50</u> 25/75
90 mm HE, M71 Projectile, Lot WC-9	91:	Glass Cones(f) Steel Cones (g)
Density am/cc	1.65	Hole Volume 157 105 149 119
Charge Wt. Ib	2.147	Hole Depth 116 116 131 119
Charge tri, is	ur naisstania r	
Total No. of Fragments:		Color: Yellow-white
For TNT	703	a second s
For Subject HE	968	Shaned charges hursting
	Market Barris	charges, demolition blocks
3 inch HE, M42A1 Projectile, Lot KC-	-5:	104 - 104 - 104 - 104 - 104
Density, gm/cc	1.65	mghlan /stenart
Charge Wt, Ib	0.872	AND THE WORLD
the second dependence		
Total No. of Fragments:	514	Method of Loading: Cast
For INI	650	
For Subject HE	0,0	Loading Density: gm/cc 50/50 10/90
		1.65 1.60
Fragment Velocity: ft/sec	2810	
At 9 ft At 251/2 ft	2580	Storage:
Density am/cc	1.66	a second a second se
Density, gill/cc		Method Dry
	Section Trees	- (less 9
Blast (Relative to TNT):	(e)	Hazara Class (Quantity-Distance)
		Compatibility Group Group I
Air:	105	
reak rressure	107	Exudation
Impulse		
Energy		Compatibility with Metals:
Air. Confined:		Dry: Copper, brass, aluminum, magnesium,
Impulse		magnesium-aluminum alloy, mild steel coated
		with acid-proof black paint, and mild steel
Under Water:		affected. Zinc plated steel is only slightly
Peak Pressure		affected.
Impulse		Wet: Stainless steel, aluminum and mild
Energy		steel coated with acid-proof black paint are
Underground:		not affected. Copper, brass, magnesium, mag-
Peak Pressure		steel plated with copper. cadmium. zinc or
Impulse		nickel are slightly affected.
Energy		Effect of Temperature on (h)
0~	76	Rate of Detonation: 50/50
Eutectic Temperature, "C:	(0	$16 \text{ hrs at, } ^{\circ}\text{C} -54 21$
gm PETN/100 gm TNT		Density, gm/cc 1.67 1.66
76°C	13.0	Rate, m/sec 7470 7440
95°C	20.3	

Preparation:

Pentolite is manufactured by either the slurry method or coprecipitation of PETN and TNT. In the slurry method PETN, in water, is stirred and heated above 80°C. TNT is added and when molten, it coats the particles of PETN. The slurry is cooled with rapid stirring and the separated granules are collected on a filter and dried below 75°C.

In coprecipitation, PETN and TNT are dissolved separately in acetone. The solutions are mixed and the explosives are precipitated simultaneously by pouring the mixed solution into cold water under vigorous agitation. The precipitated solid is collected on a filter and dried in air.

Origin:

Standardized during World War II, with the 50-50 PEIN/INT mixture being the more important for bursting charges and booster-surround charges.

References: 56

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) Philip C. Keenan and Dorothy Pipes, <u>Table of Military High Explosives</u>, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) L. C. Smith and S. R. Walton, <u>A Consideration of RDX/Wax Mixtures as a Substitute for</u> Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(e) W. R. Tomlinson, Jr., <u>Blast Effects of Bomb Explosives</u>, PA Tech Div Lecture, 9 April 1948.

(f) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W672-ORD-5723.

(g) Eastern Laboratory, du Pont, <u>Investigation of Cavity Effect</u>, Final Report, Contract W-672-ORD-5723, E. Lab, du Pont, 18 September 1943.

(h) W. F. McGarry and T. W. Stevens, <u>Detonation Rates of the More Important Military Explo</u>sives at Several Different Temperatures, <u>PATR No. 2383</u>, November 1956.

(i) Also see the following Picatinny Arsenal Technical Report on Pentolite:

<u>0</u>	1	2	3	<u>4</u>	<u>5</u>	6	7	8
1360 1420 1570	1291 1451 1651	1212 1262 1372	1133 1193 1213 1363	1284 2004	1325	1436 1466 1796	1477 1677 1737	1388 1598 1668 1838

⁵⁶See footnote 1, page 10.

Composition:		Molecular Weight: (C5H8	N4012)	316
с 19.0 ^{ОNO} 2 I 2.5 ^{СН} 2		Oxygen Balance: CO ₂ % CO %		-10 15
N 17.7 02NO-CH2-C-CH2-	-0N0 ₂	Density: gm/cc Cr;	ystal	1.77
0 60.8 ^{CH} 2		Melting Point: °C		141
C/H Ratio 0.134 ONO2		Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt:	17	Boiling Point: °C		
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	6 16	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	n Luit in	a dibertation An <u>Angel a</u>
Friction Pendulum Test:Steel ShoeCraFiber ShoeUna	ckles ffected	Vacuum Stability Test: cc/40 Hrs, at 90°C		
Rifle Bullet Impact Test: 5 Trials *	e De la St	120°C 135°C		11+
Partials 0		150°C	N.	
Burned O Unaffected O *4.86% moisture in samples	- 1.	200 Gram Bomb Sand Test: Sand, gm	ini nati	62.7
Explosion Temperature: °C Seconds, 0.1 (no cap used) 272 1 244 5 Decomposes 225 10 211		Sensitivity to Initiation: Minimum Detonating Cha Mercury Fulminate Lead Azide Tetryl	arge, gm	0.17* 0.03*
15		*Alternátive initiatir Ballistic Mortar, % TNT:	ng charges	•1µ5
20		Trauzi Test, % TNT:	(b)	173
75°C International Heat Test: % Loss in 48 Hrs	0.02	Plate Dent Test: Method	(c)	A
100°C Heat Test:	0.1	Condition Confined		Pressed Yes
% Loss, 2nd 48 Hrs	0.0	Density, gm/cc		1.50
Explosion in 100 Hrs	None	Brisance, % TNT		129
Flammability Index: Will not continue	to burn	Detonation Rate: Confinement		None
Hygroscopicity: % 30°C, 90% RH	0.0	Charge Diameter, in.		1.00
Volatility:	0.0	Density, gm/cc Rate, meters/second		1.70 8300

PEIN (Pentaerythritol Tetranitrate)

AMCP 706-177

Booster Sensitivity Test:	(c)	Decomposition Equation:	(e)	(e)	(f)
Tatal	Fressed	(Z/sec)	10-210	10-010	10-51
Wax in far 50% Detenation	2	Heat, kilocalorie/mole	47.0	50.9	52.3
Wax, m. for 50 % Detonation	2	(ΔH, kcal/mol)	161 000	108 100	1 27 1 57
Pensity and (as	5	Temperature Kange, C	. 101-255	100-120	13(-1)(
Density, gm/cc	1.0	Phase	Liquid	Solid	At melt- ing point
Heat of: Combustion, cal/am	1960	Armor Plate Impact Test:			
Explosion, cal/am	1385				
Gas Volume cc/am	790	60 mm Mortar Projecti	le:		
Formation cal/am	383	Aluminum Eineness	TT/sec		
Fusion, cal/am	5-5	Aluminum Fineness			
·,, g		500-lb General Purpose	Bombs:		
Specific Heat: cal/gm/°C	(d)				
		Plate Thickness, inch	es		
Room Temperature	0.26				
		1			
		11/4			
		11/2			
Burning Rate:		13/4			
cm/sec				***	
	and have a	Bomb Drop Test:			
cal/sec/cm/°C		T7, 2000-lb Semi-Armo	r-Piercing	Bomb vs (Concrete:
Coefficient of Expansion:		Max Safe Drop, ft			
Linear, %/°C		500-lb General Purpose	Bomb vs	Concrete:	
Volume, %/°C		Height, ft			
		Trials			
Hardness, Mohs' Scale:	1.9	Unaffected			
×		Low Order			
		High Order			
E , dynes/cm ²					
E, ID/Inch-		1000-lb General Purpos	e Bomb vs	Concrete:	
Density, gin/cc		Haisha Ka			
Compressive Strength: Ib/inch ²		Height, tt			
		Unoffected			
Vanar Brossesson					
°C mm Mercurv		Hich Order			
		nign Order			
					i la sura

PETN (Pentaerythritol Tetranitrate)

		A REAL PROPERTY AND A REAL PROPERTY OF THE
Fragmentation Test:	Shaped Charge Effectiveness, TNT =	= 100:
90 mm HE M71 Projectile Lat WC-91.	Glass Cones Ste	el Cones
Density am/ss	Hole Volume	
Charge Wt Jb	Hole Depth	
Charge Wi, ib	And a second sec	
Total No. of Fragments:	Caleri	17.14.
For TNT	Color:	wnite
For Subject HE	a where Above we	
national and a second	Principal Uses:	and heartown
3 inch HE, M42A1 Projectile, Lot KC-5:	Class B - Priming composi	tions
Density, gm/cc		
Charge Wt, Ib		
adama Baranga Care	and at the second	
Total No. of Fragments:	Method of Loading:	
For INI		N. G. MIT
For Subject HE	Loading Density: gm/cc ps	i x 10 ³
	3 5 10 20	30 40
Fragment Velocity: ft/sec	1.37 1.58 1.64 1.71	1.73 1.74
At $25\frac{1}{2}$ ft	Storage:	
Density, gm/cc		Wet
	Method	Web
	Hazard Class (Quantity-Distance)) Class 9
Blast (Relative to TNT):	77, 2020-0	cal/angle m. 1
Air:	Compatibility Group	Group M (wet)
Peak Pressure	n s volta	None
Impulse in some provident succession	Exudation	None
Energy		1 and somehow
	Bulk Modulus at Room	(i)
Air, Contined: Impulse	Temperature (250-300C):	
	$Dynes/cm^2 \times 10^{-10}$	4.60
Under Water:	Density, gm/cc	1.77
Peak Pressure	ar Caffra	
Impulse	oute shu quari i	
Energy		
Underground:	r reduced a second s	
Peak Pressure	a harring and a second s	
Impulse	Shine is a second of a	
Energy		
19.	L-Q-MpH (
	a a generation of the second sec	

Compatibility with Metals:

Dry: Copper, brass, aluminum, magnesium, magnesium-aluminum alloy, stainless steel, mild steel, mild steel coated with acid-proof black paint and mild steel plated with copper, cadmium, nickel or zinc are not affected.

Wet: Stainless steel is unaffected and aluminum only vary slightly so after prolonged storage. Copper, brass, magnesium, magnesium-aluminum alloy, mild steel, mild steel coated with acid-proof black paint and mild steel plated with cadmium, copper, nickel or zinc are affected.

Sensitivity of PETN to electrostatic discharge, joules; Through 100 Mesh: (g)

Unconfined	0.06
Confined	0.21

Solubility, grams of PEIN per 100 grams (%) of: (h)

or A	lcohol	Ac	etone	Be	nzene	To	luene
°c	2	°c	<u>%</u>	°C	<u>%</u>	<u>°c</u>	Z
0 20 40 60	0.070 0.195 0.415 1.205	0 20 40 60	14.37 24.95 30.56 42.68	0 20 40 80	0.150 0.450 1.160 7.900	0 20 40 60 80	0.150 0.430 0.620 2.490 5.850
						100 112	15.920 30.900

				B-Et	hoxy-ethyl-		
Methyl aceta	ate	Ethe	er		acetate	Chlorobe	enzene
°C	<u> 70</u>	°C	<u>%</u>	°C	76	°C	7/2
20 30 40 50	13 17 22 31	0 2 0 34.7	0.200 0.340 0.450	20 30 40 50 60	1.5 4.1 7.6 11.2 14.2	20 30 40 50 60	0.35 2.8 6.1 9.2 12.2

Ethylenedichloride		Methanol		Tetrachloroethane		tetrachloride	
°C	76	°C	<u>%</u>	<u>o</u> C	<u>%</u>	oc	<u>%</u>
10	0.9	20	0.46	20	0.18	20	0.096
30	1.5	40	1.15	30	0.27	30	0.108
50	2.6	60	2.6	40	0.40	40	0.118
				50	0.58	50	0.121

PEIN (Pentaerythritol Tetranitrate)

Isopropanol	Isobutanol	Chloroform		TNT
<u>°c</u> <u>%</u>	<u>°c %</u>	° <u>c</u> %	°C	<u>%</u>
15 0.02 20 0.0 ^h 30 0.15 40 0.36 50 0.46 Eutetic of the sy and 87% TNT at 74	20 0.27 30 0.31 40 0.39 50 0.52 ystem PETN-INT is ab 5°C.	20 0.09 out 13% PEIN	80 85 90 95 100 105 110 115 120 125	19.3 25.0 32.1 39.5 48.6 58.2 70.0 87.8 115 161

Preparation:

(Nitroglycerin and Nitroglycerin Explosives, Naoum)

8HCHO + CH₃CHO + Ca(OH)₂ \rightarrow 2C(CH₂OH)₄ + Ca(HCOO)₂ C(CH₂OH)₄ + 4HNO₃ \rightarrow C(CH₂ONO₂)₄ + 4H₂O

1. In this preparation 1940 gm of formaldehyde and 600 gm of aceteldehyde are dissolved in 90 liters of water containing 1600 gm suspended slaked lime. The reaction is complete in about 3 weeks if agitated several times a day. The solution is filtered, the calcium formate precipitated with oxalic acid, filtered off, and the water removed under reduced pressure. On cooling the mother liquor about 1200 gm crude pentaery-thritol, melting point $235^{\circ}-240^{\circ}C$ are obtained. Purification is readily effected by stirring with a little alcohol, filtering and recrystallization from water.

2. To 400 cc of strong white nitric acid, are added 100 gm of pentaerythritol (through 50 mesh), at 5° C or below, under good agitation. After addition is complete stirring, at 5° C, is continued for 15 minutes. The mixture is drowned in 3 liters of ice-water, filtered, the product washed free of acid with water and then digested 1 hour in 1 liter of hot 0.5% sodium carbonate solution. The product is filtered, and recrystallized from acetone.

Origin:

PETN was known as an explosive in 1894 when it was proposed as an addition to smokeless powders to raise their flammability and ease of combustion (German Patent <u>81,664</u> (1894). Modern methods of preparation are described by Vignon and Gerin (Compt rend <u>133</u>, 590 (1901) and German Patent 265,025 (1912) and A. Stettbacher (Z ges Schiess - Sprengstoffw <u>11</u>, 112, 182 (1916) and <u>24</u>, 259 (1929)). PETN was not used on a practical basis until after World War I.

Destruction by Chemical Decomposition:

PETN is decomposed by dissolving in 8 times its weight of technical grade acetone and burning the solution in a shallow container. If preferred, warm the acetone solution to 40° C, stir and add 7 parts by weight, to each part of PETN, of a solution of 1 part sodium sulfide (Na₂S·9H₂O) in 2 parts water heated to 80°C. The aqueous solution should be added at such a rate that the acetone solution does not boil. After mixing is complete continue stirring for one-half hour. References:57

1570

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) Ph. Naoum, Z ges Schiess - Sprengstoffw, pp. 181, 229, 267 (27 June 1932).

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) International Critical Tables.

(e) M. A. Cook and M. T. Abegg, "Isothermal Decomposition of Explosives," University of Utah, <u>Ind & Eng Chem</u>, (June 1956), pp. 1090-1095.

(f) A. J. B. Robertson, "The Thermal Decomposition of Pentaerythritol Tetranitrate, Nitroglycerin, Ethylenediamine Dinitrate and Ammonium Nitrate," J Chem Ind 67, 221 (1948).

(g) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U.S. Dept of Int, Bureau of Mines, RI 3852, 1946.

(h) Various sources in the open literature.

(i) W. S. Cramer, Bulk Compressibility Data on Several High Explosives, NAVORD Report No. 4380, 15 September 1956.

(j) Also see the following Picatinny Arsenal Technical Reports on PEIN:

0	l	2	<u>3</u>	<u>4</u>	5	6	7	8	<u>9</u>
760 1170 1260 1300 1320 1360 1380 1390 1430 1450	1041 1311 1381 1451 1561 1611 1651	772 922 1182 1192 1212 1262 1342 1352 1352 1352 1452	843 863 1063 1133 1253 1343 1493 1533	904 1274 1284 1414	1305 1325 1445 1705 1885 2125	1246 1276 1316 1376 1446 1456 1466 1556 1796	407 527 857 1247 1517 1617 1737 1797	318 838 1238 1318 1388 1568 1598 1838 2178	1379 1429 1489 1559 2179

⁵⁷See footnote 1, page 10.

Picramide (TNA) (2,4,6-Trinitroaniline)

Composition:	Molecular Weight: $(C_{G}H_{4}N_{4}O_{G})$	228
$^{\text{70}}$ C 31.5 H 1.8 $O_{0}N \rightarrow NH_{2}$ NO ₀	Oxygen Balance: CO ₂ % CO %	-56 -14
N 24.5	Density: gm/cc Crystal	1.76
0 42.2 NO	Melting Point: °C 189	9 to 190
C/H Ratio 0.500	Freezing Point: °C	м (ii)
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C Decomposes before	boiling point
Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 23 Sample Wt, mg 20	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	. absorgin .v. (6), .v. [6], gi
Friction Pendulum Test: Steel Shoe	Vacuum Stability Test: cc/40 Hrs, at	4 (1) 11 (1)
Fiber Shoe	90°C 100°C	0.9
Rifle Bullet Impact Test: Trials	120°C	n (d)
% Explosions Partials	135°C 150°C	
Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm	48.1
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10 15	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl Ballistic Mortor, % TNT:	0.30
20		100
75°C International Heat Test: % Loss in 48 Hrs 100°C Heat Test:	Plate Dent Test: Method Condition	TOI
% Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Confined Density, gm/cc Brisance, % TNT	
Flammability Index:	Detonation Rate: Confinement	None
Hygroscopicity: %	Condition Charge Diameter, in.	Pressed 0.5
Volatility:	Density, gm/cc Rate, meters/second	1.72 7300

Picramide (TNA) (2,4,6-Trinitroaniline)

AMCP 706-177

Shaped Charge Effectiveness, TNT = 100:	
Glass Cones Steel Cones	
Hole Volume	
Hole Depth	
	0.114.849.0
Color: Ye	ellow
1 and 1008 of the constraint comment of	P. S. Manager
Principal Uses: High temperature heat	
resistant explosive	
internet a brait signed in the state	
find the fast of many and and will from	
Method of Loading:	Pressed
Line R. Mainertent, "The Sector of the days	
Loading Density: gm/cc	1.72
At 30,000 psi	
Storage:	
	Ð
Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
and the second	
Exudation	None
Solubility:	
Insoluble in water, slightly s	oluble in t glacial
acetic acid, hot ethyl acetate an	d in benzen
and acetone.	
Heat of:	
	00/0
Combustion, cal/gm (a)	2962 564
Formation, cal/gm (a)	131
and the second	
동물 집안 동안 동안 감사 같은 것이 없다.	
	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth Color: Ye Principal Uses: High temperature heat resistant explosive Method of Loading: Loading Density: gm/cc At 50,000 psi Storage: Method Hazard Class (Quantity-Distance) Compatibility Group Exudation Solubility: Insoluble in water, slightly salecate an and acetone. Heat of: Combustion, cal/gm (a)

Preparation:

Five grams of picryl chloride were dissolved in 180 milliliters of absolute methanol. The solution was then saturated with anhydrous, gaseous ammonia. The time required was approximately 30 minutes. The amino derivative precipitated in 78% yield (3.6 gm) melting at 190° C (literature MP 189° C).

Origin:

Picramide (2,4,6-trinitroaniline) was first prepared in 1854 by Pisani who treated picryl chloride with ammonium carbonate (CR <u>39</u>, 853). The use of picramide, as a brisant explosive, was patended by Chemische Fabrik Griesheim 26 May 1894 (German Patent 84,628). Meisenheimer and Patzig reacted trinitrobenzene with hydroxylamine in cold alcohol solution to obtain picramide (Ber <u>39</u>, 2534 (1906)). Witt and Witte obtained the compound by nitrating a solution of aniline in glacial acetic acid or concentrated H_2SO_4 at about 5°C with concentrated HNO₃ (Ber <u>41</u>, 3091 (1908)). Holleman gives details of the prep ation from p-nitroaniline and from acetanilide (Rec trav chim 49, 112 (1930)).

Reference: 58

(a) William H. Rinkenbach, "The Heats of Combustion and Formation of Aromatic Nitro Compounds," J Am Chem Soc <u>52</u>, 116 (1930).

⁵⁸See footnote 1, page 10.

Composition:	and specific bases of	Molecular Weight:	236
% Explosive D 52		Oxygen Balance: CO ₂ % CO %	-63 -19
TNT 48		Density: gm/cc Cast	1.62
		Melting Point: °C	ha lath Seni l
C/H Ratio		Freezing Point: °C	and a set
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	100+	Boiling Point: °C	ine vereinet
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	17 19	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	Van Arriga Mangashi Mangashi Mangashi
Friction Pendulum Test:	An other as written as	Vacuum Stability Test:	TaTion
Steel Shoe Fiber Shoe	Unaffected Unaffected	cc/40 Hrs, .: 90°C	
Rifle Bullet Impact Test: Trials		- 100°C 120°C	0.37 0.68
Explosions 0		135°C	17. <u>84</u> 20. 94
Partials 0		150°C	0.7
Burned 40 Unaffected 60		200 Gram Bomb Sand Test: Sand, gm	45.0
Explosion Temperature:°CSeconds, 0.1 (no cap used)45613545Decomposes10265	Cassiperinta mp din Baudantee Bauganyana ya .	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	0.20 0.05
15 260 20 255		Ballistic Mortar, % TNT: (a)	100
20	sakha ai is mila.	Trauzi Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	0.0	Plate Dent Test: (b) Method	В
100°C Heat Test:		Condition	Cast
% Loss, 1st 48 Hrs	0.0	Confined	No
% Loss, 2nd 48 Hrs	0.05	Density, gm/cc	1.03
Explosion in 100 Hrs	None	Brisance, % INT	100
Flammability Index:	digunden fahrelden Daar vlag	- Detonation Rate: (b) Confinement	None
Hygroscopicity: % 30°C, 90% RH	0.02	Charge Diameter, in.	1.0
Volatility:		- Density, gm/cc Rate, meters/second	1.63 6970

Picratol, 52/48

Fragmentation Test:		Shaped Charge Effectiveness, TNT = 100:			
90 mm HE, M71 Projectile, Lot W	C-91:	Glass Cones Steel	Cones		
Density, gm/cc	1.61	Hole Volume			
Charge Wt, Ib	2.075	Hole Depth			
Total No. of Fragments: For TNT	703	Color: Br	own-yellow		
For Subject HE	769	Principal Uses: AD SAD projectil	es and hombs		
3 inch HE, M42A1 Projectile, Lot K	C-5:	The projection of the projection			
Density, gm/cc	1.61				
Charge Wt, Ib	0.850				
Total No. of Fragments:		Method of Logding:	Cast		
For TNT	514	Melliou of Louding.	man least and phile		
For Subject HE	487	lan neutrati	meets Jamit		
	5104	Loading Density: gm/cc	1.62		
Fragment Velocity: ft/sec	17.40.04	dia di Tana da	ware in the level wild be		
At 9 ft At 251/2 ft	2590	Storage:			
Density am/cc	1.62	3			
Density, gin/ cc		Method	Dry		
Blast (Relative to TNT):	<u>990 fham Beech Lee</u> 1 - Sendi Git	- Hazard Class (Quantity-Distance)	Class 9		
Air:		Compatibility Group	Group I		
Peak Pressure	100	e de la transforme de la t	Sillanditi, C. F.		
Impulse	100	Exudation	None at 65°C		
Energy	strading Aligned	Part of the second s			
0.024.0		Preparation:			
Air, Confined:		Picratol is made by heating T	NT to about		
impulse		90°C in a steam-jacketed melt k sive D is added slowly, without	preheating.		
Under Water:		and the mixture stirred until u	niform in com-		
Peak Pressure		position. This slurry is coole	d to about 85°C		
Impulse		component.	ammunition		
Energy					
i de se		Origin:			
Peak Pressure		Developed during World War II	as an insensi-		
Impulse		tive, melt-loaded AP bomb and p	rojectile fille		
Energy		Booster Sensitivity Test:	(c)		
Bomb Drop Test:		Condition	Cast		
Lond Drop Loove		Tetryl, gm	100		
T7, 2000-1b Semi-Armor-Pie Bomb vs Concrete:	ercing	Wax, in. for 50% Detonation Density, gm/cc	1.00 1.63		
Max Safe Dron, ft. 10.	.000-12.000				

References: 59

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(c) L. C. Smith and S. R. Walton, <u>A Consideration of RDX/Wax Mixtures as a Substitute for</u> Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(d) R. W. Drake, Fragment Velocity and Panel Penetration of Several Explosives in Simulated Shells, OSRD Report No. 5622, 2 January 1946.

(e) Also see the following Picatinny Arsenal Technical Reports on Picratol:

<u>8</u> <u>9</u>	8	<u>7</u>	<u>6</u>	5	<u>o</u>	
338 1729	1838	1737 1797	1466 1796	1885	1470	
			1956			

⁵⁹See footnote 1, page 10.

Picric Acid

And a submitted and an an an and a submitted and a submitted and a submitted and and a submitted and	States of the local division of the local di		the second s	
Composition:		Molecular Weight: (C ₆ H	13 ^N 3 ⁰ 7)	229
[%] OH C 31.5	0	Oxygen Balance: CO ₂ % CO %		-45 -3.5
и 18.5	2	Density: gm/cc	Crystal	1.76
		Melting Point: °C		122
C/H Ratio 0.656		Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt:	0-	Boiling Point: °C		
Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	05 13 17	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀		9 - Hand Hand Hand Hand Hand Hand Hand Hand
Friction Pendulum Test:		Vacuum Stability Test:		
Steel Shoe Fiber Shoe		cc/40 Hrs, at 90°C		
Rifle Bullet Impact Test: Trials		- 100°C		0.2
%		120°C		0.5
Explosions 0		150°C		
Partials 60 Burned 10		200 Cram Pamb Sand Tax		
Unaffected 0		Sand, gm	•	48.5
Explosion Temperature: °C		Sensitivity to Initiation: Minimum Detonating C	harae, am	
1		Mercury Fulminate		0.26*
5 Decomposes 320		Lead Azide		0.24*
10		Tetryl *Alternative initiati	ng charges.	
20		Ballistic Mortar, % TNT:	(a)	112
		Trauzi Test, % TNT:	(b)	101
75°C International Heat Test: % Loss in 48 Hrs	0.05	Plate Dent Test:	(c)	
		- Condition		A
100°C Heat Test:	0.02	Confined		No
% Loss 2nd 48 Hrs	0.03	Density, gm/cc		1.50
Explosion in 100 Hrs	None	Brisance, % TNT		107
Flammability Index:		- Detonation Rate: Confinement	(d) Une	confined
		- Condition	Pressed	Cast
Hygroscopicity: % 30°C, 90% RH	0.04	Charge Diameter, in.	1.0	1.25
Volatility		- Density, gm/cc	1.64	1.71
· vivility.		Rate, meters/second	5270	7350

Picric Acid

Condition	Pressed Cast	Oxygen, atoms/sec
Tetryl, am	10 5	(Z/sec)
Wax in for 50% Detonation	and the second	Heat, kilocalorie/mole
Wax am	2 0	(ΔH, kcal/mol)
Density and (as	2 0	
Density, gm/cc	1.0 1.7	Phose
Heat of:	and the second se	
Combustion, cal/gm	2672	Armor Plate Impact Test:
Explosion, cal/gm	1000	
Gas Volume, cc/am	675	60 mm Mortar Projectile:
Formation cal/am	248	Aluminum Eineness
Fusion col/cm (e)	20.4	Aluminum Fineness
Temperature, °C	122	500-Ib General Purpose Bombs;
Specific Heat: cal/gm/°C (e)	contrary in house	Territ Ma. al Creptoretti
°c		Plate Thickness, inches
0	0.235	
50	0.258	1
90	0.310	11/4
120	0.337	11/2
	September	_ 134
Burning Rate:		hiness and a
cm/sec		Bomb Drop Test:
Thermal Conductivity: (f)	eards we may have	and the object in the second se
col/sec/cm/°C Density, gm/cc	6.24 x 10 ⁻⁴ 1.406	T7, 2000-Ib Semi-Armor-Piercing Bomb vs Concrete:
Coefficient of Expansion:		Max Safe Drop, ft
Linear, %/°C		500-lb General Purpose Romb vs Concrete:
		see in ceneral raipuse sonis vis concrete.
Volume, %/°C		Height, ft
		- Trials
Hardness, Mohs' Scale:	2.1	Unaffected
		Low Order
Young's Modulus:		High Order
E', dynes/cm²		
E, lb/inch ²		1000-lb General Purpose Bomb vs Concrete:
Density, gm/cc		
		– Height, ft
Comproprive Strongthy Ib /inch?		Trials
compressive strength: ID/ Inch-		Unaffected
compressive strength: 10/ Inch-	The second s	201441.012411
Vapor Pressure:		Low Order
Vapor Pressure: °C mm Mercury		Low Order High Order
Vapor Pressure: °C mm Mercury 195 2		Low Order High Order

Picric Acid

Fragmentation Test:	Decempentation -	Shaped Charge Effectiveness, TNT = 100:				
90 mm HE, M71 Projectile, Lot WC-91:	(tare).")	Glass Cor	nes Steel Cones	Marchines		
Density, gm/cc	vasa siza i	Hole Volume		a na nàmh - n		
Charge Wt, Ib	There is a second se	Hole Depth		Neg - Sile Derektive als		
Total No. of Fragments:		Color:	Yellow			
For TNT	Appendia International		man free and a second second	199-19041		
For Subject HE	deb array Rife	Principal Uses: Formerl	y projectile f xture: and for	iller, the		
3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc	ale 1982. A marité -	manufacture of Exp	losive D	Cas Yole Romanna		
Charge Wt, Ib	sector and the sector of			tion interaction des impositions		
Total No. of Fragments: For TNT	n an Br	Method of Loading:	Press	ed alt altime t		
For Subject HE		Loading Density: gm/cc	psi x 10	3 20		
Fragment Velocity: ft/sec At 9 ft At 251/6 ft		1.40 1.50 1.57 Storage:	1.59 1.61	1.64		
Density, gm/cc		Method		Dry		
Blast (Relative to TNT):	-1-04-0-51	Hazard Class (Quantity	-Distance)	Class 9		
Air: Peak Pressure		Compatibility Group		Group I		
Impulse		Exudation		None		
Energy				de mensione		
Air, Confined: Impulse				Paidoms, M.		
		ge oppose and the second second		-		
Under Water: Peak Pressure				nhadet afgelege fil. En service sile		
Impulse				during the fit		
Energy				Density, up		
Underground: Peak Pressure		in a strand field of a		Contraidling 5		
Impulse						
Energy				Wagan Press		
			* * * * * * *	. тар Алтана Алтана		
				(A I)		

%

~3 3.96

				Ē	Picric Acid				
Solubili	ty: grams	per 100	grams (%) of: (g)					
Wa	iter	Alc	cohol	I	Benzene	T	oluene	Et	her
°c	2	°c	2	°c	2	<u>°c</u>	Z	°C	2
0 20 40 60 80 100	0.85 1.17 1.88 2.98 4.53 7.1	0 20 40	4.5 6.9 12.0	0 20 40 60	~2 9.6 27.5 59	20 60	~13 ~30	20 34•7	~
Chlor	oform	Ethyl	acetate	tetr	rbon achloride	Py	ridine	Ace	tone
°c	1/2	°c	%	°c	%	°c	%	°c	2
20 60	~2 ~6	20 30 40 50	42 50 58 69	20 60	~0.07 ~0.4	10 30 50	24 37•5 58	20 30 40 50	12 1 10 20
Me	thanol	Isop	ropyl al	cohol	Propan	101-1	Carbon di	sulfide	
°C	1/2	°c		1/2	°c	1/2	°c	2	
0 20 40 50	14 19 31 41	10 30 50		6.4 9.8 15.5	0 20 40 50	2.4 3.3 5.4 7.4	20 30	0.1 0.1	2 6
Preparat	tion: (Sur	mmary Rep	ort of N	DRC, Div	8, Vol I)				
Сене	5 + Hg(NO3)2	in an and the second	>	C6H5HgNO3	+ HNO3			(1)
C6H5	HgNO3 + N	2 ⁰ 4	11.5410. 11.5410	>	C6H5NO +	Hg(NO3)2			(2)
C6H5	NO + 2NO				C6H5N2NO3				(3a)
C6H5	N2 ^{N0} 3 + H	20		>	с6н20н +	N ₂ + HNO ₃		in immere	(3b)
C6H5	OH + HNO3	0.07 m	NO2		о ₂ NC ₆ H ₄ OH	t + н ₂ 0			(3c)
C6H5	NO	H tion and	NO ₃ rearrange	ement >	о ₂ мс _б н ₄ он	1000			(4)
02NC	COH + HNO	3	NO2	>	(02N)2C6H	1 ₃ 0н + н ₂ 0			(5)
(02N	1)2C6H2OH -	+ HNO3	NO2		(OoN) CAH	LOH + H_0			(6)

Picric Acid

The two variables of greatest importance in this process are nitric acid concentration and the effective concentration of benzene (i.e., benzene dissolved in the oxynitration solution). The optimal concentration of nitric acid is in the range 10.4 to 11.6 molar (or the equivalent of 50% to 55% by weight for pure acid). The acid concentration greatly influences the over all rate of reaction, below 10.4 molar the rate falls off rapidly, while above 10.4 molar the rates of both the oxynitration reaction and various side reactions, such as direct nitration, increase rapidly. The range mentioned above seems, in general, to give the lowest proportion of neutral nitro-compounds to nitro-phenols with, at the same time, an adequate rate of oxynitration. The oxynitration solution must be fortified frequently, or, preferably, continuously with nitric acid. Strengths of nitric acid between 95% and 98% are best, due to the smaller increase in reaction volume than if weaker acid were used. The use of absolute nitric acid requires that its direct contact with liquid benzene be avoided.

The effective concentration of benzene is probably the most critical variable affecting the proportion of neutral nitro-compounds to nitrophenols and amounts of colored by-products. Saturation of the oxynitration solution with benzene is undesirable and thus in batch processes slow benzene addition is preferable to the addition of it in one portion; in continuous processes where an excess of benzene is used the rate of agitation is important.

The concentration of mercuric nitrate catalyst does not appear to be a critical factor over a fairly wide range. Concentrations of 0.37 to 0.5 mole of mercuric nitrate per liter of oxynitration solution have been found to give satisfactory results in most cases.

A continuous process, known as the continuous solution process, works on the following cycle. The oxynitration solution is saturated with benzene by vigorous agitation with excess benzene at room temperature, the saturated solution is separated from excess benzene and circulated through a heated coil; it is then cooled to room temperature and agitated again, with benzene, which extracts the organic product and resaturates the oxynitration solution. In evaluating this process, the rate of formation of dinitrophenol per liter of reacting solution in the coil is determined; 70 gm of dinitrophenol per liter per hour is representative performance. The dinitrophenol is, of course, nitrated to picric acid.

Origin:

Picric Acid was first prepared in 1771 by Woulff who found the reaction of nitric acid and indigo yielded a dye. Hausmann isolated Picric Acid in 1778 and studied it further (Journal de physique <u>32</u>, 165 (1788)). The preparation was studied by many chemists but in 1841 Laurent established its identity (Ann chim phys III, <u>3</u>, 221 (1841)). It was used as a yellow dye until Turpin, in 1885, proposed Picric Acid as a bursting charge for high explosive shell (French Patent 167,512). The British adopted Picric Acid as a military explosive in 1888 under the name of lyddite and other nations soon began to use it as the first meltloaded high explosive. Mixtures of other explosives and Picric Acid were developed until it was gradually replaced by TNT about 1900. Today Picric Acid is used for the manufacture of Explosive D.

Destruction by Chemical Decomposition:

Picric Acid is decomposed by dissolving in 25 times its weight of a solution made from 1 part sodium hydroxide and 21 parts sodium sulfide ($Na_2S.9H_2O$) in 200 parts of water. Some hydrogen sulfide and ammonia are evolved.

References: 60

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) Ph. Naoum, Z ges Schiess-Sprengstoffw, pp. 181, 229, 267 (27 June 1932).

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.

M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.

(e) International Critical Tables.

(f) E. Hutchinson, The Thermal Sensitiveness of Explosives. The Thermal Conductivity Explosive Materials, AC Report No. 2861, First Report, August 1942.

(g) Values taken from various sources in the open literature.

(h) Also see the following Picatinny Arsenal Technical Reports on Picric Acid:

<u>1</u>	2	<u>3</u>	<u>4</u>	<u>5</u>	6	<u>7</u>	8	2
1651	132 582 1172 1352 1372	1383	694 764 874	65 425 1585	266 556 926 976 986 1446	1347 1557	1118	1549
					1556			

⁶⁰See footnote 1, page 10.

Composition:	Molecular Weight:	310
70	Oxygen Balance:	
PEIN 81	CO ₂ %	-74 - 31
Gulf Crown E Oil 19		- 10
a state inspection and the second state of a state	Density: gm/cc Hand tamped	1.35
Charge and the Annual Annual and the second grant of the	Melting Point: °C	
C/H Ratio	Freezing Point: °C	18 .enst .en
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	Boiling Point: °C	n an This said
Sample Wt 20 mg	Refractive Index, n ^D ₂₀	
Picatinny Arsenal Apparatus, in. 11 Sample Wt. ma	n ₂₅	
	n ₃₀	
Friction Pendulum Test:	Vacuum Stability Test:	
Steel Shoe Unaffected	cc/40 Hrs. at	
Fiber Shoe Unaffected	90°C	
	- 100°C	0.48
Rifle Buller Impact Test: Trials	120°C 16 hours	11+
Explosions 0	135°C	
Partials 0	150°C	
Burned 0	200 Gram Bomb Sand Test	
Unaffected 100	Sand, gm	41.6
Explosion Temperature: °C	Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)	Minimum Detonating Charge, gm	
1	Mercury Fulminate	0.20*
5 Decomposes*	Lead Azide	0.20*
10	*Alternative initiating charges.	
20	Ballistic Mortar, % TNT:	
*No value obtained.	Trauzi Test, % TNT:	
75°C International Heat Test:	Plate Dent Test: (a)	
	Method	В
100°C Heat Test:	Condition Ha	nd tamped
% Loss, 1st 48 Hrs 0.17	Confined	No
% Loss, 2nd 48 Hrs 0.00	Density, gm/cc	1.33
Explosion in 100 Hrs None	Brisance, % TNT	76
	Detonation Rate:	
Flammability Index:	Confinement	None
Human ister of 200 and 55 and 55	- Condition	Hand tamped
пудгозсорісну: % 30°С, 90% RH 0.02	Charge Diameter, in.	1.0
Volatility:	Density, gm/cc	1.37
	Rate, meters/second	7075

Fragmentation Test:		Shaped Charge Effectiveness, TNT = 100:		
90 mm HE, M71 Projectile, L	ot WC-91:	Glass Cones Stee	el Cones	
Density am/cc	1.33	Hole Volume		
Charge Wt, Ib	1.723	Hole Depth		
Total No. of Fragments:		Calari		
For TNT	703	Color:		
For Subject HE	519	Principal Uses: Plastic demoli	tion explosive	
3 inch HE, M42A1 Projectile,	Lot KC-5:	1	L'apprenden in Barry and	
Density, gm/cc	1.39			
Charge Wt, Ib	0.735	a antican		
Total No. of Fragments:		Method of Loading:	Hand tamped	
For TNT	514			
For Subject HE	428	Loading Density: om/cc	1.35	
			1.32	
At 9 ft		ferritoria foresta	and and the second second	
At 251/2 ft		Storage:		
Density, gm/cc		Method	Dry	
ast (Relative to TNT):	ana ang pantanan ang pan ta Ng panta	Hazard Class (Quantity-Distance)	Class 9	
Air:		Compatibility Group	Group I	
Impulse		Exudation		
Energy		AUX weight		
Litergy				
Air, Confined:		Urigin:		
Impulse		PIPE, a mechanical mixture	of PETN and Gulf	
Hadaa Watan		during World War II.	one on bed blace	
Peak Pressure		References: 61		
Impulse		(a) I C Cmith and E C	Fuster Dhusical	
Energy		Testing of Explosives, Part I	II-Miscellaneous	
Underground:		port No. 5746, 27 December 19	45.	
Peak Pressure		(b) S. Livingston, Proper	ties of Explosive	
		RIPE, PIPE and PEP-3, Picatin	ny Arsenal Techni	
Impulse				
Impulse Energy		cal Report 1517, 24 April 194	5.	

61See footnote 1, page 10.

Plumbatol

Composition:		Molecular Weight:	291
Lead Nitrate	70	Oxygen Balance; CO ₂ % CO %	-5.4 +9.3
.T.M.T.	30	Density: gm/cc	
	(align)	Melting Point: °C	
C/H Ratio		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C	P. C. Line &
Sample Wt 20 mg Picatinny Arsenal Apparatus, in.	13	Refractive Index, n ^D ₂₀	
Sample Wt, mg	22	n ₃₀	
Friction Pendulum Test:	and Social Control of	Vacuum Stability Test:	
Steel Shoe Fiber Shoe		cc/40 Hrs, at 90°C	
		- 100°C	
Rifle Bullet Impact Test: Trials		120°C	
%		135°C	
Explosions		150°C	
Partials			
Burned		200 Gram Bomb Sand Test:	a state of the second
Unaffected		Sand, gm	32.4
Explosion Temperature: °C	Constant Constant	Sensitivity to Initiation:	(m)de
Seconds, U.I (no cap used)		Minimum Detonating Charge, gm	
I 5 Decomposes 238		Mercury Fulminate	
10		Lead Azide	0.20
15		letryl	0.10
20		Ballistic Mortar, % TNT:	r farfert
		Trauzi Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	na Al	Plate Dent Test:	a in Company
and the second		Condition	
100°C Heat Test:		Contined	
% Loss, 1st 48 Hrs			
% Loss, 2nd 48 Hrs		Density, gm/cc	
Explosion in 100 Hrs		brisance, % INI	2 P. 94
Flammability Index:		Detonation Rate: (b) Confinement	
Hygroscopicity: %		Condition Charge Diameter, in.	
Volatility:		Density, gm/cc Rate, meters/second	2.89 4850

Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100:
90 mm HE, M71 Projectile, Łot WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Cones (a) Hole Volume 114 Hole Depth 103
Total No. of Fragments: For TNT	Color: Light yellow
For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt. Ib	Principal Uses:
Total No. of Fragments: For TNT For Subject HE	Method of Loading: Cast
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	
Blast (Relative to TNT);	Hazard Class (Quantity-Distance) Class 9
Air: Peak Pressure Impulse	Compatibility Group Group I Exudation
Air, Confined: Impulse Under Water: Peak Pressure	Origin: An explosive containing 70% lead nitrate and 30% TNT has been used in Belgium under the name of "Marcarite." References: ⁶²
Impulse Energy Underground:	(a) Eastern Laboratory, du Pont, <u>Investi-</u> gation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W-672-ORD-5723.
Peak Pressure Impulse Energy Preparation:	(b) <u>Thorpe's Dictionary of Applied Chem-</u> istry, Fourth Edition, Vol IV, Longmans, Green and Company, London - New York - Toronto, p. 464.
Plumbatol is manufactured by simple mechanical mixing of lead nitrate in molten TNT.	al returning fr

62See footnote 1, page 10.

PLX (Liquid)

Composition:	7 (Historia 112	Stoped Charge	Molecular Weight:	<u>100</u> 61	<u>95/5</u> 61
% Nitromethane Ethylenediamine	100	* 95 5	Oxygen Balance: CO ₂ % CO %	-39 -13	-48 -21
*The mixture 95/5 Nit is designated PLX (f	romethane/Et) or Picatinny	nylenediamine Liquid Explo-	Density: gm/cc	1.14	1.12
sive). See note und	er <u>Storage</u> .	data (Melting Point: °C	-29	terio con latera
C/H Ratio		and the second second	Freezing Point: °C	21	inde : with
Impact Sensitivity, 2 Kg W	$\frac{1}{10}$	$\frac{95/5}{100+}$	Boiling Point: °C	101	ati w 191.gun 1
Sample Wt 20 mg Picatinny Arsenal Appa Sample Wt, mg	ratus, in.	20 20	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀		
Friction Pendulum Test:			Vacuum Stability Test:		1.17.28
Steel Shoe Fiber Shoe	Una: Un a :	ffected ffected albema	cc/40 Hrs, at 90°C		
Rifle Bullet Impact Test:	10 Trials	5 Trials	120°C		
Explosions	0	0	135°C		
Partials	0	O		100	25/5
Burned Unaffected	0 100	0 100	200 Gram Bomb Sand Test: Sand, gm	8.1	<u>9575</u> 50.6
Explosion Temperature: Seconds, 0.1 1 5	°C <u>100</u> 430	о _с <u>95/5</u> 430	Sensitivity to Initiation: Minimum Detonating Ch Mercury Fulminate Lead Azide	arge, gm	
15		$= \frac{1}{2} \frac{(r_{i} T_{i}) - T_{i}^{-1} T_{i}}{r_{i}}$	l etryl	- x	den alimpiti și terre-
20		a an an an Anna An Anna Anna Anna	Ballistic Mortar, % TNT:	134	n filogagari i
75°C International Heat T % Loss in 48 Hrs	est:	19 <u>18-19</u> 12	Trauzi Test, % PA Plate Dent Test: Method	127	<mark>- Mader Marie.</mark> P orte P rosector anjulita
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		ente des entre ent	Condition Confined Density, gm/cc Brisance, % TNT		
Flammability Index:			Detonation Rate: 1 Confinement G	./32"* lass	1/32"* Glass
Hygroscopicity: %	1.11.		Condition I Charge Diameter, in. 1	19uid 25	Liquid 0.94
Volatility:			Density, gm/cc 1 Rote, meters/second 6 *Tube wall thickness	14 5210	1.12 6165

PLX (Liquid)

Booster Sensitivity Test: <u>N</u> Condition	itromethane	Decomposition Equation: (d) Oxygen, atoms/sec	Nitromethane 10 ^{14.6}
Tetryl, gm		Heat kilocalorie/mole	56.6
Wax, in. for 50% Detonation		(ΔH, kcal/mol)	,
Wax, gm		Temperature Range, °C	380-430
Density, gm/cc		Phase	Gaseous
Heat of:	(a)	Armor Plate Impact Test:	Charles and
Combustion, cal/gm	2030		
Explosion, cal/gm		60 mm Mortar Projectile:	
Gas Volume, cc/gm		50% Inert, Velocity, ft/sec	
Formation, cal/gm	-348	Aluminum Fineness	
Fusion, cal/gm Vaporization, cal/gm	149	500-1b General Purpose Bombs:	
Specific Heat: cal/gm/°C (b)	colours) in Federal	Dista Thiskness inches	
$C_p = 0.4209 - 0.00076t + 0.$	0000061t ²	Plate Thickness, inches	
101 1) 0 00 10 0		1	
		11/4	
		11/2	
	ange the	13⁄4	
Thermal Conductivity: cal/sec/cm/°C	- Andrea Constant - Consected by the	T7, 2000-Ib Semi-Armor-Piercing	Bomb vs Concrete:
Coefficient of Expansion:		Max Safe Drop, ft	
Linear, %/°C		500-Ib General Purpose Bomb vs	Concrete:
Volume, %/°C		Height, ft	
		Trials	
Hardness, Mohs' Scale:		Unaffected	
N		Low Order	
Toung's Modulus:		High Order	
E', dynes/cm ²			
E, lb/inch ²		1000-lb General Purpose Bomb vs	Concrete:
Density, gm/cc			
6 1 1 1 1 1 1		Height, ft	
Compressive Strength: Ib/inch ²		Trials	
	·····	Unaffectea	
Vapor Pressure:	(c)	Low Order	
°C mm Mercury		High Order	
95 Juli			
0) 444			

PLX (Liquid)

Fragmentation Test:	Shaped Charge Effectiveness, TNT $=$ 100:
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb	Glass Cones Steel Cones Mole Volume Hole Depth
Total No. of Fragments: For TNT	Color: Light yellow
3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib Total No. of Fragments:	Principal Uses: Minefield clearing Method of Loading: Pumping
For Subject HE	Loading Density: gm/cc 100 95/5
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc Flast (Relative to TNT): Air: Peak Pressure Impulse Energy	Storage: Method Components stored separately; mixed only when ready to use Hazard Class (Quantity-Distance) Compatibility Group Exudation
Air, Confined: Impulse	Minimum Propagating10095/5Thickness, in:0.50.063
Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Viscosity, centipoises: (e) Temp, 10°C 0.748 25°C 0.625 40°C 0.533 <u>Compatibility with Metals:</u> Stainless steel, mild steel and duriron not affected; corrodes brass.

Origin:

Nitromethane has been known since 1872 (Kolbe, J prakt Chem (2) 5, 427 (1872), but was available only as a laboratory product until it appeared as an industrial chemical in 1940. A number of patents have been issued for nitromethane produced as a by-product of the nitration of propane (U. S. Patent 1,967,667 (1934); British Patent 443,707 (1937); and Canadian Patent 371,007 (1938).

The development of nitromethane liquid explosives was based on information that nitromethane is sensitized to initiation and propagation of detonation by the addition of various amines. This study made at Picatinny Arsenal in 1945 indicated that mixtures of nitromethane with 5% of ethylenediamine, n-butyl-amine, or morpholine showed considerable promise for application in mine-field clearance (L. H. Eriksen and J. W. Rowen, PATR No. 1565, 17 September 1945).

References:63

(a) D. E. Holcomb and C. F. Dorsey, "Thermodynamic Properties of Nitroparaffins," Ind Engr Chem <u>41</u>, 2788 (1949).

(b) J. W. Williams, "A Study of the Physical Properties of Nitromethane," J Am Chem Soc 47, 2644 (1925).

(c) L. Medard, "Explosive Properties of Nitromethane," Mem poudr 33, 125 (1951).

(d) T. L. Cottrell, T. E. Graham and T. J. Reid, "The Thermal Decomposition of Nitromethanes," Transactions of the Faraday Society <u>47</u>, 584 (1951).

(e) F. Bellinger, H. B. Friedman, W. H. Bauer, J. W. Eastes and W. C. Bull, "Chemical Propellants: Stability of Mononitromethane," Ind Engr Chem <u>40</u>, 1320 (1948).

(f) Also see the following Picatinny Arsenal Technical Reports on Nitromethane:

<u>o</u>	<u>1</u>	<u>3</u>	<u>5</u>	6	<u>7</u>	8	2
1660	1681 1831	2113	1565 .	2016	1747	1708	1619

⁶³See footnote 1, page 10.

Composition:	Molecular Weight: (KC6H4N406) 225
$\begin{array}{c c} & & & \\ C & & 27.3 \\ H & & 0.4 \\ N & & 21.2 \end{array}$	Oxygen Balance: -60 CO ₂ % -18
$\begin{array}{c c} n & 21.2 \\ \hline 0 & 36.3 \\ \hline 0_{2}N \\ \hline \end{array} \qquad \qquad$	Density: gm/cc 2.21
к 14.8 [2	Melting Point: °C Explodes 210
C/H Ratio 0.416	Freezing Point: °C
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3; (1 1b wt) 6 Sample Wt, mg	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀
Friction Pendulum Test:Steel ShoeExplodesFiber ShoeExplodes	Vacuum Stability Test: cc/40 Hrs, at 90°C
Rifle Bullet Impact Test: Trials % Explosions Partials	100 C 120°C 135°C 150°C
Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm 44.8 43.6 Black powder fuse 9.5
Explosion Temperature:°CSeconds, 0.1 (no cap used)152501015	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.30 0.20 Lead Azide 0.10 Tetryl
20	
75°C International Heat Test: % Loss in 48 Hrs	- Trauzi Test, % TNT: Plate Dent Test: Method
100°C Heat Test: % Loss, 1st 48 Hrs 0.03 % Loss, 2nd 48 Hrs 0.05 Explosion in 100 Hrs None	Condition Confined Density, gm/cc Brisance, % TNT
Flammability Index:	- Detonation Rate: Confinement
Hygroscopicity: % 30°С, 75% RH 0.11 30°С, 90% RH 0.27	- Condition Charge Diameter, in.
Volatility:	Rate, meters/second

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Potassium Dinitrobenzfuroxan (KDNBF)

Booster Sensitivity Test:	Annal Channel	Decomposition Equation:
Condition		Oxygen, atoms/sec
Tetryl, gm		(Z/sec)
Wax, in. for 50% Detonation		(AH kcal/mal)
Wax, gm		Temperature Range, °C
Density, gm/cc		Phase
		a statement in a statement of the second statement of
Heat of:	2209	Armor Plate Impact Test:
Compustion, cary gm	725	and the second se
Explosion, cal/gm	60)	60 mm Mortar Projectile:
Gas Volume, cc/gm	004	50% Inert, Velocity, ft/sec
Formation, cal/gm		Aluminum Fineness
Fusion, cai/gm		500-lb General Purpose Bombs;
Specific Heat: cal/am/°C (b)		Easter Mary of Freedometry
°c		Plate Thickness, inches
-50	0.217	The major and the second se
0	0.217	11/4
25	0.217	114
50	0.21(172
Burning Rate:		
cm/sec		Bomb Drop Test:
Thermal Conductivity:		
cal/sec/cm/°C		T7, 2000-Ib Semi-Armor-Piercing Bomb vs Concrete:
Coefficient of Expension:		Max Safe Drop, ft
Linear, %/°C		500-lh General Purpose Romb vs Concrete:
		SUO-ID General Furpose bomb vs Concrete:
Volume, %/°C		Height, ft
		Trials the block
Hardness, Mohs' Scale:		Unaffected
× 4 4 4 1		Low Order
Found & Modulus:		High Order
E, dynes/cm ²		(1997) (1997) Andrewski (1997)
		1000-lb General Purpose Bomb vs Concrete:
Density, gm/cc		Marsha A
Companying Strongths It (in the		- Reight, ft
Compressive arrengen: ib/inch-		Trials
an a		Unaffected
Vapor Pressure:		Low Order
°C mm Mercury		High Order
		and the second
Fragmentation Test:	Shaped Charge Effectiveness, TNT $=$ 100:	
------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones Steel Cones de Maria	
Density, gm/cc	Hole Volume	
Charge Wt, Ib	Hole Depth	
	Desident in	
Total No. of Fragments:	Color: Orange to brown	
For TNT	the Body	
For Subject HE	Principal lises: Drimeny evolocity	
3 inch HF M42A1 Projectile Lat KC-5	Trimary exprosive	
Density om/cc	L UL addictară	
Charge Wt. Ib	in the second seco	
charge with its		
Total No. of Fragments:	Method of Londing: Dressed	
For TNT	Method of Lodding.	
For Subject HE		
	Loading Density: gm/cc psi x 10 ³	
Fragment Velocity: ft/sec	10 20 30 40 80 1.63 1.77 1.81 1.86 1.98	
At 9 ft	Caused .	
	Storage:	
Density, gm/cc	Method Wet	
Praticipal de la companya de la comp		
Blast (Relative to TNT):	Hazard Class (Quantity-Distance) Class 9	
	Compatibility Group Group M (wet)	
Air: Peak Pressure		
	Exudation	
Energy		
	Solubility in Water.	
Air, Confined:	gm/100 gm solvent, at:	
Impulse	30°C 0.245	
Under Water:	Stab Sensitivity:	
Peak Pressure	Density Firing Point (inch-ounces)	
Impulse	gm/cc 0% 50% 100%	
Energy	1.63 73 79 ⁸⁴	
etp. a		
Underground: Peak Pressure	1.86 12 15 18	
Impulse	1.93 11 17 21	
Energy	1.98 7 11 14	
ng professional and the second s	Activation Energy:	
	kcal/mol 82.6	
	Induction Period, sec 0.5-10	

Preparation of Potassium Salt of 4,6-dinitrobenzfuroxan: (a)

Benzfuroxan, made by the reaction of ortho-nitroaniline and alkaline sodium hypochlorite, was dissolved in 6 parts of 96% sulfuric acid and nitrated at 5° -20°C with a 4 to 1 sulfuricnitric acid mixture. The salt was prepared by neutralization of the 4,6-dinitrobenzfuroxan with potassium bicarbonate followed by recrystallization from hot water. The product forms in small golden orange plates which explode at 210°C.

Origin:

The potassium salt of 4,6-dinitrobenzfuroxan was first prepared in 1899 by von P. Drost (Ann 307, 56 (1899)).

References: 64

(a) R. J. Gaughran, J. P. Picard and J. V. R. Kaufman, "Contribution to the Chemistry of Benzfuroxan Derivatives," J Am Chem Soc <u>76</u>, 2233 (1954).

(b) C. Lenchitz, Ice Calorimeter Determination of Enthalpy and Specific Heat of Eleven Organometallic Compounds, PATR No. 2224, November 1955.

(c) Also see the following Picatinny Arsenal Technical Reports on Potassium Dinitrobenzfuroxan:

<u>2</u> 2122	<u>3</u> 2093	<u>6</u> 2146	2	2 2179		
						tar Reng M Sint Saftitions 7
						a dili milatti

⁶⁴See footnote 1, page 10.

PTX-1

Composition:		Molecular Weight:	252
70 DTV	20	Oxygen Balance:	in fir aid
RDX	30	CO ₂ %	-45
Tetryl	50		- 9
TNT	20	Density: gm/cc	1.68
		Melting Point: °C Eutectic	67
C/H Ratio	ter to and d	Freezing Point: °C	COS and I
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	14.14	Boiling Point: °C	1 topo anticata o
Sample Wt 20 mg		Refractive Index, n ^D ₂₀	
Picatinny Arsenal Apparatus, in. Sample Wt. ma		n ₂₅	
	and to com	n ₃₀	
Friction Pendulum Test:		Vacuum Stability Test:	1.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2
Steel Shoe		cc/40 Hrs, at	
Fiber Shoe		90°C	
Rifle Bullet Impact Test: Trials			3.0
%		120°C	
Explosions 20		135 C	
Partials 20			
Burned 0		200 Gram Bomb Sand Test:	
Unaffected 60		Sand, gm	54.8
Explosion Temperature: °C		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm	
1		Mercury Fulminate	0.23*
10		Lead Azide	0.22*
15		*Alternative initiating charges.	
20		Ballistic Mortar, % TNT: (a)	132
		Trauzl Test, % TNT:	
 75°C International Heat Test: % Loss in 48 Hrs 		Plate Dent Test: (b)	
		Method	В
100°C Heat Test:		Condition	Cast
% Loss, 1st 48 Hrs		Confined	No
% Loss, 2nd 48 Hrs		Density, gm/cc	1.68
Explosion in 100 Hrs		Brisance, % TNT	127
Flammability Index:		Detonation Rate:	None
		Condition	wone
Hygroscopicity: %		Charge Diameter in	Cast
30°C, 90% RH, 15 days	0.00	Density om/cc	1.0
Volatility:		Rate meters/second	7655
		Rule, meters/second	(0))

Fragmentation Test:		Shaped Charge Effectiveness, $TNT = 1$	00:
90 mm HE, M71 Projectile, Lot WC-91		Glass Cones Steel C	Cones
Density, gm/cc	1.64	Hole Volume	
Charge Wt, Ib	2.180	Hole Depth	
Total No. of Fragments:		Color:	
For TNT	703	A CONTRACTOR OF A CONTRACTOR OF A CONTRACT OF	
For Subject HE	999	Principal Uses: Land mines and de	molition
3 inch HE, M42A1 Projectile, Lot KC-5		charges	
Density, gm/cc	1.63	and the second	
Charge Wt, Ib	0.864	the second second second	
Total No. of Fragments:		Method of Loading:	Cast
For TNT	514		
For Subject HE	685	Loading Density: am/cc	1 68
Fragment Velocity: ft/sec	in in in the		1.00
At 9 ft	2690		and the second secon
At 251/2 ft	2460	Storage:	
Density, gm/cc	1.64	Method	Dry
Blast (Relative to TNT):		— Hazard Class (Quantity-Distance)	Class 9
Air:	(đ)	Compatibility Group	Group I
Peak Pressure	111		C-0
Impulse	109	Exudation Ex	udes at 65°C
Energy			
Air, Confined:		Preparation:	
Impulse		The ternary explosive system	consisting of
Under Weter		appropriate weight of water-wet	RDX to a tetry-
Peak Pressure		tol (40/60) previously melted i	n a steam-
Impulse		are continued until all the wat	er is evaporated
Energy		and the mixture is uniform in c	omposition.
Underground:		Composition B.	B SCOLUL OF HEA
Peak Pressure		Compatibility with Metals:	
Impulse		Dry: Aluminum. mild steel n	ot affected.
Energy			
Booster Sensitivity Test: (c)		Wet: Aluminum, mild steel n	ot affected.
Condition Pre	essed Cast		
Wax, in. for 50% Detonation	94 1.82	2	
Density, gm/cc	.61 1.68	3	

307

The possibility of employing ternary mixtures to obtain explosives having greater power and higher brisance than binary mixtures was suggested by the analysis of Russian 76 mm, armor piercing high explosive rounds (PATR No. 1311, 17 July 1943). The Russian type ternary explosives, based on the composition and laboratory studies of such mixtures, were indicated to be effective pressed fillers. In conducting a preliminary study of <u>castable</u> ternary explosive mixtures suggested by the Russian fillers, a mixture consisting of <u>RDX/tetryl/TNT</u>, designated PTX-1 was developed which had explosive and physical properties offering considerable advantage for military applications (PATR No. 1360, 27 October 1943; and 1379, 11 January 1944).

A PTX-3 composition, prepared by the addition of Haleite to 40/60 tetrytol, also offered promise but limited to applications where the charge would not be required to withstand storage at 65° C without exudation.

References: 65

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(d) W. R. Tomlinson, Jr., <u>Blast Effects of Bomb Explosives</u>, PA Tech Div Lecture, 9 April 1948.

(e) Also see the following Picatinny Arsenal Technical Reports on PTX-1:

<u>o</u>	2	3	6	<u>7</u>	2	
1530	1402	1623	1466 1506	1437	1379 1429 1469	

⁶⁵See footnote 1, page 10.

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		and the second
Composition:	Molecular Weight: 244	243
יערס און איז	Oxygen Balance:	26
TTY - TT	$CO_2 \% -33$	- 30
PEIN 28 - 26		w myseles
INT 28 - 33	Density: gm/cc	1.70
	Melting Point: °C Eutectic	75
C/H Ratio	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	A. DH. dool S.
Bureau of Mines Apparatus, cm 35 Sample Wt 20 mg	Refractive Index, no	e-diamate a th
Picatinny Arsenal Apparatus, in.	nD	
Sample Wt, mg	1125 D	
1 and 1 and 1 and 1 and 1		Art and Article
Friction Pendulum Test:	Vacuum Stability Test:	
Steel Shoe Crackles	cc/40 Hrs, at	
Fiber Shoe	- 100°C	2.6
Rifle Bullet Impact Test: Trials	120°C	11+
%	135°C	
Explosions 60	150°C	
Partials 0		
Burned 0	200 Gram Bomb Sand Test:	
Unaffected 40	Sand, gm	56.9
Explosion Temperature: °C	Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)	Minimum Detonating Charge, gm	Public Provid
Products and the second	Mercury Fulminate	0.21
5	Lead Azide	0.00
10	Tetryl	0.00
20	Ballistic Mortar, % TNT: (a)	138
and satisfy at long and as the own Part with	Trauzl Test, % TNT:	and the second second
75°C International Heat Test:	Plate Dent Test: (b)	
	Method	В
100°C Heat Test:	Condition	Cast
% Loss, 1st 48 Hrs	Confined	No
% Loss. 2nd 48 Hrs	Density, gm/cc	1.71
Explosion in 100 Hrs	Brisance, % TNT	141
Solondan ing funts beta sundantle, tett	— Detonation Rate:	
Flammability Index:	Confinement	None
and the second	- Condition	Cast
Hygroscopicity: %	Charge Diameter, in.	1.0
30°C, 90% RH, 15 days 0.00	Density, gm/cc	1.70

PTX-2

Fragmentation Test:	the Western	Shaped Charge Effectiveness, TNT $=$	00:
90 mm HE, M71 Projectile, Lot WC-	91:	Glass Cones Steel	Cones
Density, gm/cc	1.68	Hole Volume ~130	
Charge Wt, Ib	2.226	Hole Depth	
Total No. of Fragments:		Calu	
For TNT	703	Color:	
For Subject HE	1128	Principal Uses Shaned changes	
3 inch HE, M42A1 Projectile, Lot KC	-5: (timler)	Fragmentation ch	arges
Density, gm/cc	1.70		
Charge Wt, Ib	0.897	M. Maria and	
Total No. of Fragments:		Method of Londing:	Coot
For TNT	514	Method of Lodding.	Cast
For Subject HE	750		test: June 1
and the second		Loading Density: gm/cc	1.70
Fragment Velocity: ft/sec	2002	el la superior	the factor tennes
At 25½ ft	2850	Storage:	
Density, gm/cc	1.70		
		Method	Dry
Blast (Relative to TNT):	Send, am	Hazard Class (Quantity-Distance)	Class 9
Air:	(d)	Compatibility Group	Group I
Peak Pressure	113	H11	Constantine of the Constant
Impulse	113	Exudation	None at 65°C
Energy			
Air, Confined:		Preparation:	
Impulse	A STREET ALL PROPERTY AND	The ternary explosive system	consisting of
Under Weter	 C. Surf InnetT. 	RDX, PEIN and TNT is prepared by	y adding the
Peak Pressure	Plate David West	tolite (30/70) previously melte	d in a steam-
Impulse	Coltrad	jacketed melt kettle. Heating	and stirring
Energy	enskielus – D	are continued until all the wat and the mixture is uniform in c	er is evaporated
Undergraund	taire i	PTX-2 is also prepared by adding	g water-wet
Peak Pressure	 D. Municipal 	The of the composition B.	
Impulse	9°	Compatibility with Metals:	an a shaka pag
Energy	mail mit control.	Dry: Aluminum, mild steel no	ot affected.
Booster Sensitivity Test: (a	2)	Wet: Aluminum not affected.	niter (1975) (1997) (1997) Niter (1997)
Condition Pre	essed Cast		and many streng plit
Tetryl, gm [] Wax, in, for 50% Detensition []	87 0 20		
nun, in in jup Deconacion			constitution for the fact

Origin:

The possibility of employing ternary mixtures to obtain explosives having greater power and higher brisance than binary mixtures was suggested by the analysis of Russian 76 mm, armorpiercing high explosive rounds (PATR No. 1311, 17 July 1943). The Russian type ternary explosives, based on the composition and laboratory studies of such mixtures, were indicated to be effective pressed fillers. In conducting a preliminary study of castable ternary explosive mixtures suggested by the Russian fillers, a mixture consisting of RDX/PETN/TNT, designated PTX-2 was developed which had explosive and physical properties offering considerable advantage for military applications (PATR No. 1360, 27 October 1943; and 1379, 11 January 1944).

A PTX-4 composition, prepared by the addition of Haleite to 30/70 Pentolite, also offered promise but because of border-line stability in accelerated stability tests, PTX-4 must be proven by long term storage to be acceptable for use in standard ammunition.

References: 66

(a) L. C. Smith and E. G. Eyster, <u>Physical Testing of Explosives</u>, Part III - <u>Miscellaneous</u> Sensitivity Tests; Performance Tests, <u>OSRD Report No.</u> 5746, 27 December 1945.

(b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(c) L. C. Smith and S. R. Walton, <u>A Consideration of RDX/Wax Mixtures as a Substitute for</u> Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(d) W. R. Tomlinson, Jr., <u>Blast Effects of Bomb Explosives</u>, PA Tech Div Lecture, 9 April 1948.

(e) Also see the following Picatinny Arsenal Technical Reports on PTX-2:

<u>o</u>	2	<u>3</u>	<u>4</u>	<u>5</u>	6	8	<u>9</u>
1530	1482	1483 1623	1414	1445	1466	1838	1379 1429

66See footnote 1, page 10.

PVA-4

Composition:	Molecular Weight:	217
RDX 90	Oxygen Balance: CO ₂ % CO %	- 37 -10
Polyvinyl Acetate 8	Density: am/cc Pressed	1.60
Dibutylphthalate 2	Molting Point: °C	
	Softening Point: °C	92
C/H Ratio	Freezing Point: °C	L-XPI A
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 39	Boiling Point: °C	aud millionistr F. 107 Strama
Sample Wt 20 mg	Refractive Index, n ^D ₂₀	
Picatinny Arsenal Apparatus, in. 9	n ^D ₂₅	
Sample Wt, mg ±3	n ₃₀	
Friction Pendulum Test: Steel Shoe Crackles Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C	a. (a). 1
	- 100°C	0.45
Rifle Bullet Impact Test: 5 Trials *	120°C	0.88
%	135°C	Mar
Explosions 20	150°C	11+
Partials	anna A sha bha i ta 'ana bui ta sanna	<u>, a 1.6,</u>
Burned 60	200 Gram Bomb Sand Test:	-0 -
*100 trials at -46°C - Unaffected	Sand, gm	58.5
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 330 5 Decomposes 375 10 265	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	0.22
20	Ballistic Mortar, % TNT:	
	Trauzl Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method	
100°C Heat Test:	Condition	
% Loss, 1st 48 Hrs 0.10	Confined	
% Loss, 2nd 48 Hrs 0.06	Density, gm/cc	
Explosion in 100 Hrs None	Brisance, % TNT	
	- Detonation Rate:	
Flammability Index:	Confinement	None
	- Condition	Cast
Hygroscopicity: % 30 [°] C, 90% RH 0.20	Charge Diameter, in.	1.0
	Density, gm/cc	1.60
Volatility: 55°C, vacuo, 6 hrs 0.03	Rate, meters/second	7910

PVA-4

	Shaped Charge Effectiveness, TNT = 10	00:
90 mm HE, M71 Projectile, Lot WC-91;	Glass Cones Steel C	ones
Density, am/cc	Hole Volume	
Charge Wt, Ib	Hole Depth	
Total No. of Fragments:		White
For TNT	Color:	White
For Subject HE		
	Principal Uses: Demolit	tion charges
3 inch HE, M42A1 Projectile, Lot KC-5:		
Density, gm/cc		
Charge Wt, Ib	tarinest innerk mitter Productor 9	
Total No. of Fragments:	Method of Loading: Pressed or	. extruded
For TNT		
For Subject HE	Loading Density: am/cc	1.60
rooment Velocity: ft/sec		
At 9 ft		
At 251/2 ft	Storage:	
Density, gm/cc	Method	Dry
Blast (Relative to TNT):	Hazard Class (Quantity-Distance)	Class 9
	Compatibility Group	Group I
Air: Peak Pressure	company and	
Impulse	Exudation No	one at 71 ⁰ C
Energy		
Air, Confined:	Plasticity:	
Impulse	-40°C	Cracked
Under Water:	0.50	0.0
Peak Pressure	25 C	0.3
Impulse		
Energy		
Underground		
Peak Pressure		
Peak Pressure Impulse		

PVA-4

Preparation:

Explosive PVA-4, a semi-plastic composition of Canadian origin, consists of 90% RDX, 8% polyvinyl acetate and 2% dibutylphthalate (DBP). This formulation was developed by Dr. Sutherland of Shawinigan Chemicals, Ltd. In evaluating various types of polyvinyl acetate commercially available in the United States, a type obtained from Union Carbide and Carbon, under the industrial named or designation "AYAT" was the most promising coating for RDX in the proportions RDX/PVA(AYAT)/DBP 92/6/2.

A practical method of preparing this composition was by the addition of a solution of the coating agent to an aqueous RDX slurry. Based on the quality of the product and the pellet densities obtained, a procedure of adding an acetone solution of PVA + DBP to a hot water slurry of RDX, under agitation, was adopted as standard.

References: 67

(a) See the following Picatinny Arsenal Technical Reports on PVA-4: 1532 and 1634.

⁶⁷See footnote 1, page 10.

PVN (Polyvinyl Nitrate)

Composition:	Molecular Weight: (C2H3NO3) n	(89) _n
с 27 н 3. ¹ 4 I	Oxygen Balance: CO ₂ % CO %	-45 - 9
(H ₂ C-CH-ONO ₂) _n N 15.6	Density: gm/cc	
0 54	Melting Point: °C (Soft Pb)	50
C/H Ratio 0.203	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: 14,86%N	Boiling Point: °C	
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 4 Sample Wt, mg	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	Canani) Canani Alia Jana K
Friction Pendulum Test:Steel ShoeCracklesFiber ShoeUnaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C	
Rifle Bullet Impact Test: Trials	- 100°C 16 hours	11+
%	120°C 10 hours	11+
Explosions	150°C	
Partials		
Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm	49.9
Explosion Temperature: °C Seconds, 0.1 (no cap used)	Sensitivity to Initiation: Minimum Detonating Charge, gm	athe touch
1 de	Mercury Fulminate	5.7 m m
10	Tetryl	
15		
20		
75°C International Heat Test:		Ni makani karan Manisi
% Loss in 48 Hrs	Method	
100°C Heat Test	Condition	
% Loss, 1st 48 Hrs 1.9	Confined	
% Loss, 2nd 48 Hrs 2.1	Density, gm/cc	
Explosion in 100 Hrs None	Brisance, % TNT	
Flammability Index:	- Detonation Rate: Confinement	equinit
Hygroscopicity: % 30°C, 90% RH 0.62	Condition Charge Diameter, in.	
Volatility:	Density, gm/cc Rate, meters/second	

Fragmentation Test:	Maintalor Weight	Shaped Charge Effectiveness, TN	T = 100: modulation (
90 mm HE, M71 Projectile, I	Lot WC-91:	Glass Cones S	Steel Cones
Charge Mite like	an 1931	Hole Polante	14 aC 18
Charge Wt, ID	service and end		bigs - w - v
Total No. of Fragments: For TNT)	Color:	5 D
For Subject HE	Social Court	Principal Uses:	Contraction Contraction
3 inch HE, M42A1 Projectile	, Lot KC-5:	1994 (1997) (1997) 1997 - 1997 (1997)	Inquire Final Second
Density, gm/cc	in edut evidential		Sandia We alto and
Charge Wt, Ib	$\frac{1}{m_{1}^{2}}$, P Toley Marine	instation Microsoft in 12 Remove Microsoft
Total No. of Fragments:	_http://www.automatics.com	Method of Loading:	
For TNT	WELL AND AND SHALL STREET		the Contraction Provident Provident
For Subject HE	14 Jack (14 14 14 14 14 14 14 14 14 14 14 14 14 1	Loading Density: gm/cc	en line line. Anti-
Fragment Velocity: ft/sec	044C		the second s
At 9 ft			here is a set in the set of the
At 251/2 ft	C1 881	Storage:	and desires 2
Density, gm/cc	2497	Method	101.4 (24
Blast (Relative to TNT):	ang "bawa	Hazard Class (Quantity-Distand	ce)
Air:	i standiski piteka kulo stanova Alexandri stanova stanova s	Compatibility Group	Exploritor Takerater
	and share she made	Exudation	1 I I I I I I I I I I I I I I I I I I I
Eperav	n ta Al hiber I		8
Lifergy	iverta T		01
Air, Confined:	· · · · · · · · · · · · · · · · · · ·	65.5 C KI Test:	21
Impulse	DIT 28 petrol studied	Minutes	60+
Under Water:	1. C. P. Well, Bridger	134.5°C Heat Test:	
Peak Pressure	Physics Rank Taxi	Salmon Pink	20
Impulse	0.0007-0-10	Red Fumes	25
Energy	maltria (*)	Explodes	300+
Underground	basilen.	240-Hour Hydrolysis Test:	ni i Bh tet "lijkd fil
Peak Pressure	2 Junit Stanson	% HNO2	5.07
Impulse	de la constante d		Edulation in 1907
Energy	D. Investion Parts	Heat of:	and the summer should be stored
	Lowmon Hooth	Combustion, cal/gm	2960
	notHbno7	Explosion, cal/gm	900
	al parada agasto	Gas Volume, cc/gm	· 838
	Daming witers 0	annealthal a search an annealthal a	
	beside datation site?		Blander

Preparation:

Polyvinyl alcohol is mixed with acetic anhydride. The mixture is cooled to $-5^{\circ}C$ and the nitric acid is added slowly while the mass is being stirred. The temperature is controlled by the rate of acid addition so that when all the acid has been added the temperature does not rise above $20^{\circ}C$.

When the nitration is complete, the mixture is drowned by allowing a fine stream of the syrupy liquid to flow from the nitrator and mix intimately with a large stream of water. This causes the product to precipitate in a fine state.

The finely divided precipitate is purified by boiling in frequent changes of water.

Origin:

The first preparation of polyvinyl nitrate was reported in 1929 by solution of polyvinyl alcohol in concentrated sulfuric acid and treatment with nitrating acid at a temperature not over 50° C. (German Patent 537,303). Later patents issued relative to polyvinyl nitrate included U. S. Patent 2,118,487 (1938) and German Patent 737,199 (1943).

) C Hean Taun 11 Lun, 191 AB Hes 11 Lun, 201 AB Hes 11 Lun, 201 AB Hes		

RIPE

Composition: %		Molecular Weight:		230
RDX	85	Oxygen Balance: CO ₂ % CO %		-70 -35
Gulf Grown E 011	15	Density: gm/cc Hand t	amod	1 07
		Melting Point: °C		1.31
C/H Ratio		Freezing Point: °C		and the function of the
Impact Sensitivity, 2 Kg Wt:	53	Boiling Point: °C		
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	13 25	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	1997 - 1997 1977 - 1997 1975 - 1983)	and and a second se Second second s Second second s
Friction Pendulum Test: Steel Shoe Fiber Shoe	Unaffected Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C		
Rifle Bullet Impact Test:TrialsExplosions0Partials0		100°C 120°C 135°C 150°C		0.34 0.56
Burned 0 Unaffected 100		200 Gram Bomb Sand Test: Sand, gm		40.1
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes; no val 10	Lue obtained	Sensitivity to Initiation: Minimum Detonating Ch Mercury Fulminate Lead Azide Tetryl	arge, gm	0.20
15 20		Ballistic Mortar, % TNT:	(a)	118
		Trauzl Test, % TNT:		
75°C International Heat Test: % Loss in 48 Hrs		Plate Dent Test: Method	(b)	В
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs	0.03	Condition Confined Density, gm/cc	Hand	No 1.37
Explosion in 100 Hrs	None	Brisance, % TNT		85
Flammability Index:		Detonation Rate: Confinement		None
Hygroscopicity: % 30°C, 90% RH	0.04	Condition Charge Diameter, in.	Hand	l tamped 1.0
Volatility:		Density, gm/cc Rate, meters/second		1.37 7390

Fragmentation Test:		Shaped Charge Effectiveness, TNT	= 100:
90 mm HE, M71 Projectile, Lot WC-91:		Glass Cones St	eel Cones
Density, gm/cc	1.36	Hole Volume	
Charge Wt, Ib	1.766	Hole Depth	
Total No. of Fragments:	State State	Color:	White
For TNT	.(03		
For Subject HE	592	Principal Uses: Plastic demol	ition explosive
3 inch HE, M42A1 Projectile, Lot KC-5:			
Density, gm/cc	1.42		
Charge Wt, Ib	0.756	and the second se	
Total No. of Fragments:		Method of Loading: H	and tamped
For TNT	514	And Antida Andreas (All and	out maintain not for
For Subject HE	501	Loading Density: am/cc	1.37
Fragment Velocity: ft/sec	7.601		
At 9 ft	2650	C1	
At 251/2 ft	2310	Storage:	
Density, gm/cc	1.395	Method	Dry
Blast (Relative to TNT):	1999 (1999) 1999 (1997)	Hazard Class (Quantity-Distance	e) Class 9
Air:		Compatibility Group	Group I
Peak Pressure		None at 85°C	in 30 hrs
Impulse		Exudation None at 95 C Exudes at 105	5° C in 48 hrs
Energy			
Air Confined:		Origin:	
Impulse		RIPE, a mechanical mixture	e of RDX and Gulf
		Crown E Oil, was developed i	in the United State
Under Water:		during world war II.	
Impulse		References:00	
Energy		(a) L. C. Smith and E. G.	Eyster, Physical
Lifeigy		Sensitivity Tests: Performan	nce Tests. OSRD Re-
Underground:		port No. 5746, 27 December 1	1945.
Peak Pressure		(b) D. P. MacDougall, Me	thods of Physical
Impulse		Testing, OSRD Report No. 80	3, 11 August 1942.
Energy		(c) Also see the following	ng Picatinny Arsens
Preparation:		Technical Reports on RIPE:	1713, 1695 and 1517

⁶⁸See footnote 1, page 10.

Silver Azide

Composition:	Molecular Weight: (AgN ₃) 150		
N 28.0 Mark and a second secon	Oxygen Balance: -5 CO ₂ % -5 CO % -5		
Ag - N = N = N	Density: gm/cc Crystal 5.1		
	Melting Point: °C (a) 251 Decomposes rapidly above melting point to		
C/H Ratio	Freezing Point: °C silver and nitrogen.		
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 6	Boiling Point: °C		
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3 Sample Wt, mg 18	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀		
Friction Pendulum Test:PA Small ApparatusSteel ShoeDetonatesFiber ShoeDetonates	Vacuum Stability Test: cc/40 Hrs, at 90°C		
Rifle Bullet Impact Test: Trials % reasonation Explosions %	100°C 120°C 135°C		
Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm (b) Black powder fuse 18.9		
Explosion Temperature: °C Seconds, 0.1 (no cap used) 310 1	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl		
	Ballistic Mortar, % TNT:		
Similari (n)	Trauzi Test, % Hg(ONC) ₂ (c) 88		
 75°C International Heat Test: % Loss in 48 Hrs 	Plate Dent Test: entertain diama Method entertain		
100°C Heat Test:	Condition		
% Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs	Density, gm/cc		
Explosion in 100 Hrs	Brisance, % TNT		
Flammability Index:	Detonation Rate: Confinement		
Hygroscopicity: % (b) 25°C, 100% RH 0.04	Charge Diameter, in.		
Volatility: 75°C, 24 hrs 0.00	Density, gm/cc Rate, meters/second		

Silver Azide

ragmentation Test:	Shaped Charge Effectiveness, Titl = 100.	
90 mm HE M71 Projectile, Lot WC-91:	Glass Cones Steel Cones	
Density gm/cc	Hole Volume	
Charge Wt Jb	Hole Depth	
Charge Wt, ib		
Total No. of Fragments:	Color: White to gra	ıy
For TNT	no so coll a at heath of the dated to a structure of	11 1 1 10
For Subject HE	Principal Uses: Initiators	1
3 inch HE, M42A1 Projectile, Lot KC-5:	prove and in specific and of terminal in the	
Density, gm/cc	with data whith an one one are could all the	
Charge Wt, Ib	die land in the bound is an interest of the area	
	STRAME DATITION AND ADDRESS CONTRACTOR	
Total No. of Fragments:	Method of Loading: Pressed	
For INI	and a substantial second s	- <u>2</u> -10-10-00-00-00-00-00-00-00-00-00-00-00-
For Subject HE	Loading Density: gm/cc Variable	
	manage of an internet and the antiper or a relation of a	
Fragment Velocity: Tt/sec At 9 ft	with the second s	7,01111
At 251/2 ft	Storage:	
Density, gm/cc	Method	t
Blast (Relative to TNT):	Hazard Class (Quantity-Distance) Cla	ass 9
	Compatibility Group	oup M
Air:	Company Croup	1.
	Exudation Not	ne
Impulse		
Energy		ann de
Air, Confined:	Initiating Efficiency:	
Impulse	Grams Required to Give Complete Initiation of TNT 0.	(c) 02-0.0
Under Water:	Solubility in 100 gm Solvent	
Peak Pressure	at Room Temperature:	
Impulse	Solvent	ams
Energy	Water (b) 0.	006
Underground:	Ammonium hydroxide So	Tuble
Peak Pressure	Ether (b) 0.	017
Impulse	Ethyl alcohol, 95% 0.	006
Energy	Acetone 0.	015
Explosive Power: (f)	Unaffected by water and CO2. (d)
Kilogram meters 192,000	Heat of:	
% Mercury Fulminate 1.097	Explosion, cal/gm (c. d) 45	2

Silver Azide

Preparation:

 $\operatorname{NaN}_3 + \operatorname{AgNO}_3 \longrightarrow \operatorname{AgN}_3 + \operatorname{NaNO}_3$

Prepare the following aqueous solutions:

a. 5% NaN₂, sodium azide, 50 cc

b. 25% AgNO2, silver nitrate, 25 cc

The silver nitrate solution is placed in a 200 cc conductive rubber beaker equipped with a hard wood stirrer operated by an air motor. The sodium azide solution is placed in a separatory funnel fastened in a ring stand above the beaker containing the silver nitrate. A long cord (10 ft) is fastened to the stopcock of the separatory funnel so that the funnel can be emptied by remote control. The silver nitrate solution is now stirred very rapidly and the sodium azide is slowly run into the nitrate solution. Stirring is continued for 5 minutes. The contents of the beaker are filtered through folded filter paper and washed free of sodium azide and silver nitrate with distilled water.

Silver azide should be stored under water in a conductive rubber container. This preparation will yield approximately 7 grams.

The preparation should be conducted under a hood and behind a barricade. The product obtained by the above procedure has a very fine particle size, almost colloidal. Very fine silver azide is safer to handle and is just as efficient and stable as the large, coarse crystalline material (Ref b). When a thin film of fine silver azide is precipitated on mercury fulminate, tetryl, etc., these substances are as efficient weight for weight as pure silver azide (Ref g). White silver azide is less affected by light than mercury or lead azide (Ref h). Long colorless crystals which explode on breaking are obtained from ammonium hydroxide.

Origin:

Silver azide was first prepared in 1890-1 by T. Curtius (Ber 23, 3032; Ber 24, 3344-5) by passing hydrazoic acid (HN_3) into neutral silver nitrate solution. Taylor and Rinkenbach prepared pure "collodial" aggregates and showed its sensitivity depends upon its particle size (Army Ordnance 5, 824 (1925). Silver azide was found in a detonator of foreign ammunition for the first time in 1945 (Ref i).

References:69

(a) A. R. Hitch, "Thermal Decomposition of Certain Inorganic Trinitrides," J Am Chem Soc 40, 1195 (1918).

(b) C. A. Taylor and Wm. H. Rinkenbach, "Silver Azide: An Initiator of Detonation," <u>Army</u> <u>Ordnance</u>, Vol 5, p. 824 (1925).

(c) E. De W. S. Colver, High Explosives, London and New York, p. 527.

(d) A. Stettbacher, Spreng u. Schiesstoffe, Rascher, Zurich, p. 97 (1948).

- (e) A. Marshall, Explosives, 2nd Ed, Vol II, p. 767, London.
- (f) A. Stettbacher, Z ges Schiess-Sprengstoffw 10, pp. 193-214 (1915).

⁶⁹See footnote 1, page 10.

(g) F. Blechta, Chim et Ind Special No. 921-5 (June 1933); C. A. 28, 646.

(h) L. Wohler and W. Krupko, Berichte 46, 2047-2050 (1913).

(i) F. G. Haverlak, Examination of 120/45 MM HE Shell, Italian (FMAM-464), PATR No. 1515, 10 April 1945.

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Tetracene

Composition:	Molecular Weight: (C2H8N100)	188
с 12.8 н 4.3 Ш мн мн	Oxygen Balance: CO ₂ % CO %	-60 -43
$\begin{array}{c} n \\ n \\ 74.4 \\ nH_{-} \end{array} = \begin{array}{c} n \\ n \\ nH_{-} \end{array} = \begin{array}{c} n \\ nH_{-} \\ nH_{-} \\ nH_{-} \end{array}$	Density: gm/cc At 3000 psi	1.05
0 8.5	Melting Point: °C Explodes	140-160
C/H Ratio 0.068	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	
Sample Wt 20 mg Picatinny Arsenal Apparatus, in.2; (8 oz wt) Sample Wt, mg	8 Refractive Index, n ^D ₂₀ 8 n ^D ₂₅ n ^D ₃₀	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C	2 18 5
Rifle Bullet Impact Test: Trials % Explosions Partials	120°C 135°C 150°C	
Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm Black powder fuse 4.0	28.0
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 160 10	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	0.40
15 20	Ballistic Mortar, % TNT:	
	Trauzi Test, % TNT: (a)	61
75°C International Heat Test: % Loss in 48 Hrs 0.5	Plate Dent Test: Method	
100°C Heat Test:	Condition	
% Loss, 1st 48 Hrs 23.2	Confined	
% Loss, 2nd 48 Hrs 3.4	Density, gm/cc	
Explosion in 100 Hrs None		
Flammability Index:	Detonation Rate: Confinement	
Hygroscopicity: % 30 ^o C, 90% RH 0.77	Condition Charge Diameter, in.	
Volatility:	Density, gm/cc Rate, meters/second	

Tetracene

ragmentation Test:	Shaped Charge Effectiveness, INI = 10		
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones Steel Cones Hole Volume		
Density, gm/cc			
Charge Wt, Ib	Hole Depth		
Total No. of Fragments:	Color: Pale	yellow	
For TNT	and the second second second second second second		
For Subject HE	Principal Uses: Priming compositi	ons and	
3 inch HE, M42A1 Projectile, Lot KC-5:	detonators		
Density, gm/cc			
Charge Wt, Ib	in all the set of a new part of the set		
	then)		
Total No. of Fragments:	Method of Loading:	Pressed	
For TNT		CLP 91 X 0	
For Subject HE	Loading Density: am/cc	1. Heren I.	
	At 3000 psi	1.05	
Fragment Velocity: ft/sec At 9 ft	TO DOTATION OF THE PARTY OF THE PARTY OF THE		
At 251/2 ft	Storage:		
Density, gm/cc	Method	Wet	
Blast (Relative to TNT):	Hazard Class (Quantity-Distance)	Class 9	
Alar	Compatibility Group	Group M	
Air: Peak Pressure			
Impulse	Exudation		
Energy			
hermonical and some second states and second	Solubility:		
Air, Confined:	Dreatically incoluble in wate	er, alcohol	
angulae An	acetone, ether, benzene, carbon	tetrachlorid	
Under Water:	or ethylenedichloride.		
Peak Pressure	Sensitivity to Electrostatic	1. 1	
Impulse	Discharge, Joules:	(b)	
Energy	Unconfined	0.010	
Underground:	Confined	0.012	
Peak Pressure	Heat OI:	658	
Impulse	Explosion, cal/gm Gas Volume. cc/gm	1190	
Energy	Tritisting Pfficiency.		
	Tetracene is not efficient i	n initiating	
	high explosives.		
	and the second se		

Tetracene

Preparation:

(Rinkenbach and Burton, Army Ordnance 12, 120 (1931)).

Tetracene is prepared by dissolving 5 gms of aminoguanidine dinitrate in 30 cc of water, cooling to 0° C and mixing with a solution of 2.5 gms of sodium nitrate in 15 cc of water. The temperature is maintained at about 10° C and 0.5 gm of acetic acid is added. The tetracene separates out and is washed with water, alcohol and ether. It is then dried.

Tetracene may also be prepared by placing aminoguanidine sulphate and sodium nitrite in a large beaker and adding water heated to 30°C. The heat of reaction causes the mixture to boil; after standing for two or three hours the separated tetracene is filtered off, washed thoroughly and dried.

Origin:

Tetracene was first prepared in 1910 by Hoffman and Roth (Ber <u>43</u>, 682) who also studied its chemical reactions and determined its structure (Hoffman et al, Ber <u>43</u>, 1087, 1866 (1910); Ber <u>44</u>, 2496 (1911); and Ann <u>380</u>, 131 (1911)). W. H. Rinkenbach and O. Burton made an extensive study of tetracene and described its manufacture and explosive properties (Army Ordnance <u>12</u>, 120 (1931)).

Destruction by Chemical Decomposition:

Tetracene is decomposed by adding it to boiling water and continuing boiling for some time to insure complete decomposition.

References: 70

(a) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) F. W. Brown, D. H. Kusler and F. C. Gibson, <u>Sensitivity of Explosives to Initiation</u> by <u>Electrostatic Discharges</u>, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

(c) Also see the following Picatinny Arsenal Technical Reports on Tetracene:

<u>o</u>	<u>1</u> <u>3</u>	<u>4</u>	<u>7</u>	8	<u>9</u>	
1450	11 453	1104 2164	407	318	859 2179	

70See footnote 1, page 10.

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Composition:	Molecular Weight: (C ₁₂ H ₅ N ₅ 0 ₈) 347
$\begin{array}{c} 70 \\ C \\ 41.6 \\ \end{array}$	Oxygen Balance: -85 CO.2 % -30
H 1.4 NO2	Density: gm/cc
N 20.0	Melting Point: °C Pure 1, 3, 6, 8-isomer 296
0 37.0 C/H Ratio 1.032	Freezing Point: °C
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C
Bureau of Mines Apparatus, cm100+Sample Wt 20 mgPicatinny Arsenal Apparatus, in.18Sample Wt, mg14	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C
Rifle Bullet Impact Test: Trials % Explosions	- 100°C 0.2 120°C 0.2 135°C 150°C
Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm 41.3
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 470 10	Sensitivity to Initiation:Minimum Detonating Charge, gmMercury FulminateLead Azide0.20Tetryl0.25
15 20	Ballistic Mortar, % TNT:
5.1.5 <u>7</u> (158)	Trauzi Test, % TNT:
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method
100°C Heat Test: 0.15 % Loss, 1st 48 Hrs 0.15 % Loss, 2nd 48 Hrs 0.05 Explosion in 100 Hrs None	Condition Confined Density, gm/cc Brisance, % TNT
Flammability Index:	Detonation Rate: Confinement
Hygroscopicity: % 30 [°] C, 90% RH 0.01	- Condition Charge Diameter, in.
Volatility:	Density, gm/cc Rate, meters/second

90 mm HE, M71 Projectile, Lot WC-91: Glass Cones Steel Cones Density, gm/cc Hole Volume Charge Wr, (b Glass Cones Steel Cones Total No. of Frogments: For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Density, gm/cc Color: Light yellow Principal Use: Component of igniter and gyrotechnic compositions For TNT For Subject HE For TNT For Subject HE Loading Density: gm/cc Method of Loading: Fregment Velocity: fr/sec A 25% ft Density, gm/cc Storage: Method Dry Hozard Class (Quantity-Distance) Class 9 Compatibility for Water: Psi ⁰ ° Peak Pressure Impulse Energy Solubility in Water, gm/200 gm (%), at:: Impulse Solubility in Water, gm/200 gm (%), at:: Impulse Solubility Peak Pressure Insoluble Impulse Solubilities: Programmed Solubility in Water, gm/200 gm (%), at:: Solubility Solubilities: Impulse Solubilities:	Fragmentation Test:	Shaped Charge Effectiveness, TNT =	100:
Totel No. of Fragments: For TNT For Subject HE Idght yellow 3 inch HE, M42Al Projectile, Lot KC-5: Density, gm/cc Density, gm/cc Colors: Charge Wt, Ib Method of Loading: Totel No. of Fragments: Pressed For TNT For Subject HE For Subject HE Loading Density: gm/cc Fragment Velocity: ft/sec Air: Peak Pressure Method Dry Hozard Class (Quantity-Distance) Class 9 Air: Peak Pressure Solubility in Water, gm/loo gm (\$), st: Impulse 95°C 0.10 Under Water: Solubility in Water, gm/loo gm (\$), st: 95°C Very soluble Concerts Solubility in Water, gm/loo gm (\$), st: Impulse Solubility in Water, gm/loo gm (\$), st: Solubility Vitrobenzene Very soluble Solubility Peak Pressure Insoluble Energy Underground: Peak Pressure Solubilities: Peak Pressure Insoluble Solubility Impulse Energy Solubility Peak Pressure Insolu	90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Stee Hole Volume Hole Depth	I Cones
For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib Total No. of Fragments: For Subject HE For Subject HE Bensity, gm/cc Fragment Velocity: ft/sec At 25% ft Density, gm/cc Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Energy Underground: Peak Pressure Impulse Energy Density: Peak Pressure Impulse Peak Pressure Impulse Peak Pressure Impulse Peak Pressure Impu	Total No. of Fragments: For TNT	Color:	ight yellow
3 inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Density, gm/cc Density, gm/cc Charge Wt, lb Method of Loading: Totel No. of Fregments: Method of Loading: For TNT For Subject HE Loading Density: gm/cc Loading Density: gm/cc Fragment Velocity: ft/sec Air: Peak Pressure Method Impulse Energy Air: Peak Pressure Impulse Solubility in Water, gm/loo gm (\$), at: Impulse Solubilities: Solubility Solubilities: Solubility Solubility Method Dry Air: 95°C Peak Pressure Solubility in Water, gm/loo gm (\$), at: Impulse Solubility Peak Pressure Very soluble Method Energy Matery Construction Insoluble Benzene Insoluble Energy Energy Method Energy Under Yoter: Solubile Peak Pressure Insoluble Energy Energy	For Subject HE	Bringing Hann Component of it	
Density, gm/cc Charge Wt, lb Total No. of Fregments: For TNT For Subject HE Leading Density: gm/cc Fragment Velocity: ft/sec At 25½ ft Density, gm/cc Blest (Reletive to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Energy Solubility in Water; gm/100 gm (\$), at: 95°C 0.10 Qualitative Solubilities: Solubility Nitrobenzene Meressure Impulse Energy Solubility in Water; 95°C 0.10 Qualitative Solubilities: Solubility Mitrobenzene Very soluble Acetone Solubile Breacene Insoluble Charoform Insoluble Breacene Insoluble Breacene Insoluble Breacene Insoluble Breachonettrachloride Insoluble	3 inch HE, M42A1 Projectile, Lot KC-5:	pyrotechnic com	positions
Charge Wt, Ib Total No. of Fragments: For TNT For Subject HE Loading Density: gm/cc Fragment Velocity: ft/sec A1 9 ft A1 25½ ft Density, gm/cc Blest (Relative to TNT): Blest (Relative to TNT): Hazard Class (Quantity-Distance) Class 9 Air: Peak Pressure Impulse Energy Air, Confined: Impulse Denk Pressure Impulse Denk Pressure Impulse Berergy Solubility in Water, gm/loo gm (\$), at: 95°C 0.10 Qualitative Solubilities: Solubility Impulse Energy Underground: Peak Pressure Impulse Energy Park Pressure Impulse Energy Peak Pressure Impulse Energy Energy Energy <td>Density, gm/cc</td> <td></td> <td></td>	Density, gm/cc		
Totel No. of Fragments: Method of Loading: Pressed For TNT For Subject HE Loading Density: gm/cc Fragment Velocity: ft/sec At 9 ft Loading Density: gm/cc Density, gm/cc Storage: Dry Blest (Relative to TNT): Hazard Class (Quantity-Distance) Class 9 Air: Peek Pressure Compatibility Group Exudation Impulse Energy Solubility in Water, gm/100 gm (%), at: 95°C 0.10 Under Water: 95°C 0.10 Qualitative Solubilities: Solubility Impulse Solvent Solubility Solubility Impulse Solvent Solubility Insoluble Peek Pressure Insoluble Energy Solubilities: Solubility Witerobenzene Solubility Solubility Insoluble Energy Underground: Peek Pressure Insoluble Energe Insoluble Impulse Energy Energy Insoluble Insoluble Energy Witerobenzene Insoluble Ether Insoluble Benzene Insoluble Ins	Charge Wt, Ib	ed in polyter gant	
For TNT Frequent Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc Storage: Blast (Relative to TNT): Hazard Class (Quantity-Distance) Air: Peak Pressure Impulse Energy Air, Confined: gm/l00 gm (\$), at: Impulse gm/l00 gm (\$), at: Impulse Solubility in Water, gm/l00 gm (\$), at: Impulse Solubilities: Impulse Solubility in Water, gm/l00 gm (\$), at: Impulse Solubility in Water, gm/l00 gm (\$), at: Impulse Solubility in Water, gm/l00 gm (\$), at: Impulse Solubility Energy Solubility Underground: Yery soluble Peak Pressure Insoluble Impulse Energy Underground: Yery soluble Peak Pressure Insoluble Impulse Theoletic energy Peak Pressure Insoluble Impulse Theoletic energy Energy Solubility Energy Insoluble Energy Energy Energy E	Total No. of Fragments:	Method of Loading:	Pressed
For Subject HE Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc Bleat (Relative to TNT): Bleat (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Impulse Peak Pressure Impulse Peak Pressure Impulse Dudier Water: Peak Pressure Impulse Peak Pressure Impulse Dudier Water: Peak Pressure Impulse Dudier Solubility in Water, gm/100 gm (\$), at: Peak Pressure Impulse Solubility in Water, gm/100 gm (\$), at: Peak Pressure Impulse Solubility in Nater, gm/co gm (\$), at: Peak Pressure Impulse Underground: Peak Pressure Impulse Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Peak Pressure Impulse Peak Pressure Impulse Peak Pressure Impulse Peak Pressure Impulse Peak Pressure Impulse	For TNT	- Contraction -	The second s
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc Blest (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Energy Air, Confined: Impulse Energy Under Water: Peak Pressure Impulse Energy Under Water: Peak Pressure Impulse Energy Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Energy Energy <td< td=""><td>For Subject HE</td><td>Loading Density: gm/cc</td><td>and the Share</td></td<>	For Subject HE	Loading Density: gm/cc	and the Share
At 9 ft At 25½ ft Density, gm/cc Storage: Blast (Relative to TNT): Hazard Class (Quantity-Distance) Class 9 Air: Peak Pressure Compatibility Group Impulse Exudation Exudation Air, Confined: gm/100 gm (%), at: 95°C 0.10 Under Water: 95°C 0.10 Qualitative Solubilities: Impulse Solvent Solubility Solubility Under Water: 95°C 0.10 Qualitative Solubilities: Solubility Nitrobenzene Very soluble Impulse Energy Nitrobenzene Very soluble Choroform Impulse Energy Energe Insoluble Energe Underground: Peak Pressure Insoluble Energe Insoluble Impulse Energy Energe Insoluble Energe Insoluble Energy Energy Energe Insoluble Insoluble	Fragment Velocity: ft/sec	and an an an and the second the second	
Density, gm/cc Method Dry Blest (Relative to TNT): Hazard Class (Quantity-Distance) Class 9 Air: Peak Pressure Compatibility Group Impulse Energy Exudation Air, Confined: gm/100 gm (%), at: 0.10 Under Water: 95°C 0.10 Very Solubility Solubilities: Solubility Impulse Solvent Solubility Impulse Solvent Solubility Peak Pressure Insoluble Solubility Impulse Energy Solvent Solubility Underground: Peak Pressure Insoluble Insoluble Impulse Energy Solvent Solubility Energy Nitrobenzene Very soluble Acetone Solubile Insoluble Benzene Insoluble Insoluble Chloroform Insoluble Insoluble Energy Energy Ether Insoluble	At 9 ft At 25½ ft	Storage:	Longini, telus-sitik
Blest (Relative to TNT): Hazard Class (Quantity-Distance) Class 9 Air: Peak Pressure Compatibility Group Impulse Exudation Energy Solubility in Water, Air, Confined: gm/100 gm (\$), at: Impulse 95°C 0.10 Under Water: 95°C 0.10 Peak Pressure Gualitative Solubilities: Solubility Impulse Solvent Solubility Energy Nitrobenzene Very soluble Underground: Peak Pressure Solubile Impulse Solvent Solubile Energy Nitrobenzene Very soluble Acetone Solubile Solubile Benzene Insoluble Chloroform Impulse Energy Ether Insoluble Energy Ether Insoluble Acetone Soluble Ether Insoluble Chloroform Impulse Ether Insoluble Insoluble Ether, petroleum Insoluble Ether Insoluble Ether, petroleum Insoluble <td>Density, gm/cc</td> <td>Method</td> <td>Dry</td>	Density, gm/cc	Method	Dry
Air: Peak Pressure Impulse Exudation Energy Solubility in Water, gm/100 gm (%), at: Air, Confined: Impulse 95°C Under Water: Peak Pressure Impulse 0.10 Underground: Peak Pressure Impulse Solubilities: Underground: Peak Pressure Impulse Solvent Solvent Solubility Nitrobenzene Very soluble Actone Soluble Impulse Energy Underground: Peak Pressure Nitrobenzene Impulse Energy Energy Energy Mitrobenzene Very soluble Actone Soluble Energy Energy	Blast (Relative to TNT):	Hazard Class (Quantity-Distance)	Class 9
Peak Pressure Impulse Impulse Exudation Air, Confined: Solubility in Water, Impulse $95^{\circ}C$ 0.10 Under Water: $95^{\circ}C$ 0.10 Peak Pressure Qualitative Solubilities: 95°C 0.10 Underground: Solvent Solubility Solubility Peak Pressure Solvent Solubility Impulse Solvent Solubility Underground: Peak Pressure Very soluble Acetone Soluble Impulse Energy Insoluble Energy Energe Insoluble Mitrobenzene Very soluble Acetone Soluble Energy Energe Insoluble Energy Energe Insoluble Benzene Insoluble Insoluble Ether Insoluble Insoluble Ether, petroleum Insoluble Insoluble	Air:	Compatibility Group	
Impulse Solubility in Water, Energy Solubility in Water, Main See 95°C 0.10 Under Water: 95°C 0.10 Peck Pressure Qualitative Solubilities: 95°C 0.10 Underground: Solvent Solubility Solubility Peck Pressure Solvent Solubility Impulse Solvent Solubility Underground: Peck Pressure Nitrobenzene Very soluble Peck Pressure Insoluble Energy Solubility Underground: Peck Pressure Insoluble Energe Impulse Energy Solubility Insoluble Energy Energy Insoluble Insoluble Energy Energy Insoluble Insoluble Energy Energy Insoluble Insoluble Energy Energy Insoluble Insoluble Ether Insoluble Insoluble Insoluble Ether, petroleum Insoluble Insoluble Insoluble	Peak Pressure	Exudation	
Air, Confined: Solubility in Water, Impulse $gm/100 \ gm (\%), \ at:$ Under Water: $95^{\circ}C$ 0.10 Peak Pressure Qualitative Solubilities: Impulse Solvent Solubility Energy Nitrobenzene Very soluble Duderground: Peak Pressure Nitrobenzene Very soluble Impulse Solvent Solubility Nischoform Impulse Energy Nischoform Insoluble Energy Energy Energy Nischoform Insoluble Energy Energy Energy Soluble Soluble	Impulse		
Air, Confined: Impulse Solubility in Water, gm/100 gm (%), at: Under Water: Peak Pressure Impulse 95°C 0.10 Qualitative Solubilities: 95°C 0.10 Under Water: Peak Pressure Impulse Solvent Solubility in Water, gm/100 gm (%), at: Underground: Peak Pressure Impulse Solvent Solubility Underground: Peak Pressure Impulse Nitrobenzene Energy Very soluble Soluble Energy Solvent Insoluble Insoluble Energy Ether Insoluble Ether, petroleum Insoluble	Energy		b)
Under Water: 95°C 0.10 Peak Pressure Impulse Solvent Solubilities: Impulse Solvent Solubility Peak Pressure Nitrobenzene Very soluble Impulse Solubile Benzene Insoluble Impulse Carbontetrachloride Insoluble Energy Ether Insoluble Ether Insoluble Ether, petroleum	Air, Confined: Impulse	Solubility in Water, gm/100 gm (%), at:	
Under Water: Qualitative Solubilities: Peak Pressure Solvent Energy Solvent Underground: Acetone Peak Pressure Insoluble Impulse Benzene Impulse Chloroform Impulse Energy Energy Energy	Tous Two is int	95°C	0.10
Impulse Solvent Solubility Energy Nitrobenzene Very soluble Underground: Acetone Soluble Peak Pressure Insoluble Insoluble Impulse Carbontetrachloride Insoluble Energy Ether Insoluble Energy Ether, petroleum Insoluble	Under Water:	Qualitative Solubilities.	
EnergySolventSolubilityUnderground: Peak Pressure ImpulseNitrobenzeneVery soluble SolubleImpulse EnergyBenzene CarbontetrachlorideInsoluble Insoluble Ether Ether, petroleum	Impulse	guarioa vive borabili vies.	
Underground: Peak Pressure ImpulseNitrobenzene AcetoneVery soluble Soluble Benzene Chloroform Ether Ether, petroleumImpulse EnergyEther Insoluble Insoluble	Energy	Solvent	Solubility
Underground: Acetone Soluble Peak Pressure Insoluble Insoluble Impulse Carbontetrachloride Insoluble Energy Ether Insoluble Ether, petroleum Insoluble	Land Initia	Nitrobenzene	Very soluble
Impulse Insoluble Energy Insoluble Ether Insoluble Ether, petroleum Insoluble	Underground:	Acetone Benzene	Soluble
Energy Carbontetrachloride Insoluble Ether Insoluble Ether, petroleum Insoluble	reak Pressure	Chloroform	Insoluble
Ether, petroleum Insoluble	Eneroy	Carbontetrachloride	Insoluble
 Negerore spinitory in 10% or 6 to 140 Negerore spinitory in 10% or 6 to 140 Negerore spinitory Negerore spinitory 	Linergy International	Ether, petroleum	Insoluble
Vojariliteja Vojariliteja		and the second management of the second s	
Yokuthike a to be a second a s			

Tetranitrocarbazole (TNC)

Preparation:



Sulfonation: Fifty-six gms of carbazole is dissolved in 320 gms of H_2SO_4 (96%, specific gravity 1.84). The solution is agitated during the addition of the carbazole and the temperature maintained at 25°-35°C. After the addition of the carbazole is completed, the agitation is continued and solution completed by raising the temperature to $80^\circ-85^\circ$ C and maintaining this temperature for one hour. The sulphate is now cooled to 20° C.

<u>Nitration:</u> The sulfonate solution is slowly added to 168 gms of HNO_3 (Plant grade specific gravity 1.525 at 15°C) maintaining the temperature at 30° to 50°C. (Time required - 1 hour 25 minutes). The temperature is then gradually raised to 70° to 75°C and maintained for one hour after which the temperature is raised to 85° to 90°C and held for one hour, then lowered to room temperature before drowning.

Drowning: The nitration mixture is drowned by pouring it into 2 to 3 volumes of ice and water.

Filtering: The separated light yellow product is filtered on a Buchner Funnel and washed with water twice to remove most of the acid.

<u>Purification:</u> The INC is placed in hot water (95[°] to 100[°]C) and boiled for five to ten minutes with rapid agitation, allowed to settle then filtered and washed once. This procedure is repeated twice, making a total of three "boilings." The final wash is acid free.

Drying: The TNC is spread in a thin layer and dried at 100° to 110°C for four hours.

Yield: 73.3%.

Melting Point of TNC as prepared: 280°C (compares to 296°C for pure 1,3,6,8-isomer in preceding data).

Origin:

The preparation of Tetranitrocarbazole (TNC) was first reported in 1880 by C. Graebe (Ann 202, 26 (1880)) who nitrated carbazole with 94% nitric acid. Similar procedures were followed by R. Escales (Ber <u>37</u>, 3596 (1904)) and P. Zierch (Ber <u>42</u>, 3800 1909)). However, G. L. Ciamician and P. P. Silber observed the formation of four isomeric TNC's when acetyl carbazole was treated with fuming nitric acid (Gazz chim ital <u>12</u>, 272 1882)). In 1912 and 1913 patents were issued to the dyestuff manufacturer, Casella and Company, covering the preparation of polynitrocarbazoles (German Patent 268,173 and French Patent <u>464</u>,538). The Casella process of

Tetranitrocarbazole (INC)

preparing polynitrocarbazoles by dissolving carbazole in sulfuric acid and treating the solution of sulfonic acids with strong nitrating agents is essentially the process used today in the United States. The crude product, thus prepared, contains principally 1,3,6,8-TNC (W. Borsche and B. G. B. Scholten Ber 50, 596 (1917) and about 10% of the 1,2,6,8-TNC isomer (D. B. Murphy et al J Am Chem Soc $\overline{75}$, 4289 (1953). TNC was used in explosives by the Germans during World War II.

References: 71

(a) D. B. Murphy, F. R. Schwartz, J. P. Picard and J. V. R. Kaufman, "Identification of Isomers Formed in the Nitration of Carbazole," J Am Chem Soc, <u>75</u>, 4289-4291 (1953).

(b) S. Livingston, <u>Preparation of Tetranitrocarbazole</u>, PA Chemical Research Laboratory Report No. 136,330, 11 April 1951.

(c) D. B. Murphy et al, Long Range Basic Technical Research Leading to the Development of Improved Ignition Type Powders - The Chemistry of Tetranitrocarbazole, PA Memorandum Report No. 22, 2 September 1952.

(d) S. Livingston, Development of Improved Ignition Type Powders, PATR No. 2267, July 1956.

(e) Also see the following Picatinny Arsenal Technical Reports on Tetranitrocarbazole:

<u>o</u>	2	<u>3</u>	4	<u>7</u>
2180	1802	1973	1984	1647
				1937

⁷¹See footnote 1, page 10.

2,4,2',4'-Tetranitro-oxanilide (TNO)

		and a second
Composition:	Molecular Weight: $(C_{14}H_8N_6O_{10})$	420
70 С 40.0 С — С І ЛН	Oxygen Balance: CO ₂ %	-84 - 31
H 1.9 \longrightarrow NO \longrightarrow NO		- 51
\mathbb{N} 20.0 $\int \int \mathcal{D}_2^{2} \int \mathcal{D}_2^{2}$	Density: gm/cc	
0 38.1	Melting Point: °C Decomposes	313
C/H Ratio 0.735 NO2 NO2	Freezing Point: °C	in the second
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	in the local design
Sample Wt 20 mg	Refractive Index, n ^D ₂₀	
Picatinny Arsenal Apparatus, in. 30	n ₂₅	
Sample Wt, mg	n ₃₀	
Friction Pendulum Test:	Vacuum Stability Test:	fees we are a
Steel Shoe Unaffected	cc/40 Hrs, at	
Fiber Shoe Unaffected	90°C	
Diffe Bullet Impact Test: Trials	- 100°C	
	120°C	0.11
Explosions	135°C	
Partials	150°C	and the second second
Burned	200 Gram Bomb Sand Test:	
Unaffected	Sand, gm	16.3
Explosion Temperature: °C	Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)	Minimum Detonating Charge, gm	
] editeboli	Mercury Fulminate	0.00
5 392		0.20
		0.2)
20	Ballistic Mortar, % TNT:	
	_ Trauzl Test, % TNT:	and the second second second
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test:	
	- Method	
100°C Heat Test:	Condition	
% Loss, 1st 48 Hrs 0.07	Density am/cc	
% Loss, 2nd 48 Hrs 0.00	Brisance % TNT	
Explosion in 100 Hrs None		
Flammability Index:	- Detonation Rate: Confinement	
Hygroscopicity: % 30°C, 90% RH Trace	- Condition Charge Diameter, in.	
Volatility:	Density, gm/cc Rate, meters/second	

2,4,2',4'-Tetranitro-oxanilide (TNO)

Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100:
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones Steel Cones
Density, gm/cc	Hole Volume
Charge Wt, Ib	Hole Depth
Total No. of Fragments:	Color: Light vellow
For TNT	
For Subject HE	Principal Uses: Component of black powder type
3 inch HE, M42A1 Projectile, Lot KC-5:	and pyrotechnic compositions
Density, gm/cc	Barraghi (Al. 2) - S. (Al. 1996)
Charge Wt, Ib	 Monitoria (A. examples of the second sec second second sec
Total No. of Fragments:	Method of Loading, Pressed and extruded
For TNT	compositions
For Subject HE	Loading Density: gm/cc
Fragment Velocity: ft/sec	tida Soliei (mund Tast
At 9 ft At 25½ ft	Storage:
Density, gm/cc	Method Drv
Blast (Relative to TNT):	Hazard Class (Quantity-Distance) Class 9
Air:	Compatibility Group
Peak Pressure	Shamba, A. E. Sana, and S. Sana, Ale
Impulse	Exudation
Energy	
	Solubility, gm/100 cc Solvent, in:
Air, Confined: Impulse	°c %
and a set	Water 100 <0.10
Peak Pressure	Nitrobenzene 150 >15
Impulse	Qualitative Solubilities:
Energy	Solvent Solubility
(3)+70	Ethyl alcohol Insoluble
Underground:	Benzene Insoluble
Peak Pressure	Butyl acetate Insoluble Carbontetrachloride Treoluble
Impulse	Ethyl ether Insoluble
Energy	Acetic acid Soluble
	Caustic potash Soluble
	Dimethyl formamide Very solub
	and the second s

2,4,2',4'-Tetranitro-oxanilide (TNO)





Oxanilide:

Two parts of oxalic acid are mixed with one part of aniline in a round bottom flask. The mixture is stirred and heated until the reaction is complete as evidenced by the cessation of effervescence. The mass is cooled to room temperature, poured into several volumes of water $(21^{\circ}-24^{\circ}C)$, filtered on a Büchner funnel and washed free of oxalic acid with water and then washed free of aniline with acetone. The oxanilide is air dried to remove the acetone and then dried at $100^{\circ}-110^{\circ}C$.

Tetranitro-oxanilide (INO):

A 5 liter round bottom flask is equipped with a stirrer of a type which will produce a downward "swirl." The flask is surrounded with a water jacket for hot and cold water. Fifteen hundred grams (1.5 kilograms) of 98% plant grade nitric acid is placed into the flask. Five hundred (500) grams of oxanilide is slowly added to the acid under rapid agitation while the temperature is maintained below 40° C. After the addition of the oxanilide is completed $(2\frac{1}{2}-3 \text{ hrs})$, the agitation is continued 10-15 minutes. The temperature is then raised to 80° C over a period of one hour and maintained at $80^{\circ}-85^{\circ}$ C for 3 hours. The acid slurry is then cooled to room temperature and drowned by pouring over cracked ice. The product is filtered on a Büchner funnel and washed with water until it is almost acid free. The filter cake is placed in a beaker and sufficient water added to form a "slurry." Live steam is run into the "slurry" under agitation for 10 minutes. The slurry is filtered and the residue washed. The latter treatment of the "slurry" is repeated until the wash water is found to be neutral to

2,4,2',4'-Tetranitro-oxanilide (TNO)

litmus paper. The TNO is washed with alcohol, then acetone, air dried and finally dried at 100°-110°C.

Yield = 90% to 97.5% of theoretical.

Origin:

A. G. Perkin in 1892 obtained tetranitro-oxanilide directly by heating a solution of finely powdered oxanilide in nitric acid. He also obtained the same compound by the action of a cooled mixture of nitric and sulfuric acids on oxanilide and precipitating the product by pouring the solution into water (J Chem Soc <u>61</u>, 460 (1892).

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(a) S. Livingston, Development of Improved Ignition Type Powders, PATR No. 2267, July 1956.

(b) D. Dubrow and J. Kristal, Substitution of Tetranitro Oxanilide and Hexanitro Oxanilide for Tetranitro Carbazole, PA Pyrotechnic Research Laboratory Report 54-TF 1-88, 20 December 1954.

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⁷²See footnote 1, page 10.

Composition:	and and an include	Molecular Weight: $(C_7H_5N_50_8)$	287			
H h 7 h	-NO ₂	Oxygen Balance: CO ₂ % CO %	-47 - 8			
\mathbb{N} 24.4	T ^{N0} 2	Density: gm/cc Crystal	1.73			
0 44.6		Melting Point: °C	130			
C/H Ratio 0.420	^D 2	Freezing Point: °C				
Impact Sensitivity, 2 Kg Wt:	06	Boiling Point: °C				
Bureau of Mines Apparatus, cm Sample Wt 20 mg - Picatinny Arsenal Apparatus, in. Sample Wt, mg	8 18	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀				
Friction Pendulum Test:	and a left in a state of the	Vacuum Stability Test:				
Steel Shoe	Crackles	cc/40 Hrs, at				
Fiber Shoe	Unaffected	90°C				
Rifle Bullet Impact Test: Trials		- 100°C	0.3			
06		120°C	1.0			
Explosions 13		135°C	and a second second			
Partials 54		150°C	11+			
Burned 10		200 Gram Bomb Sand Test:				
Unaffected 23		Sand, gm	54.2			
Explosion Temperature: °C Seconds, 0.1 (no cap used) 340	in the last of the	Sensitivity to Initiation: Minimum Detonating Charge, am				
1 314		Mercury Fulminate	0.20*			
5 Ignites 257		Leod Azide	0.10*			
10 238		Tetryl.				
15 236		*Alternative initiating charges.				
20 234		Ballistic Mortar, % TNT: (a)	1,30			
75°C International Heat Tests		_ Trauzi Test, % TNT: (b)	125			
% Loss in 48 Hrs	0.01	Plate Dent Test: (c) Method A	в			
100°C Heat Test:		Condition Pressed P	ressed			
% Loss, 1st 48 Hrs	0.1	Confined Yes	No			
% Loss, 2nd 48 Hrs	0.0	Density, gm/cc 1.50 1.59	1.36			
Explosion in 100 Hrs	None	Brisance, % TNT 116 115	96			
Flammability Index:	244	- Detonation Rate: Confinement	None			
Hygroscopicity: % 30°C, 90% RH	0.04	- Condition Charge Diameter, in.	Pressed 1.0			
Volatility: 25 [°] C	0.00	- Density, gm/cc Rate, meters/second	1.71 7850			

Tetryl

Booster Sensitivity Test: (d) Condition Pressed	Decomposition Equation: Oxygen, atoms/sec 10 ^{15.4} (h) 10 ^{12.9}
Tetryl om 100	(Z/sec)
Way in far 50% Detanation 2.01	Heat, kilocalorie/mole 30.4 34.9
	(AH, Kcal/mol) Temperature Range °C 211-260 132-164
Wax, gm	Diana Liquid Liquid
Density, gm/cc 1.50	Phase Diquia Diquia
Heat of: Combustion, cal/gm 2925	Armor Plate Impact Test:
Explosion, cal/gm 1080-1130	60 mm Mortar Projectile:
Gas Volume, cc/gm 760	50% Inert, Velocity, ft/sec
Formation, cal/gm -14	Aluminum Fineness
Fusion, cal/am a (e) 22.2	· Prostanty Activity Second - Prostanting
Temperature, C 127	500-lb General Purpose Bombs:
Specific Heat: cal/gm/°C (e)	
	Plate Thickness, inches
-100 0.182	- stale and second
- 50 0.200	1 Annual Annua
50 0.223	11/4
100 0.236	11/2 . of the the full and the full and the full attack
	13/4
Burning Rate:	A ermigd null
cm/sec	Bomb Drop Test:
(2)	- Contraction of the second se
Thermal Conductivity: (1) $cal/sec/cm/^{\circ}C 5.81 \times 10^{-4} at 1.394 gm/cc$ $6.83 \times 10^{-4} at 1.528 gm/cc$	T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:
	Max Safe Drop, ft
Linear, %/°C	500-lb General Purpose Bomb vs Concrete:
Volume, %/°C	Height ft
Hardness, Mohs' Scale:	
	Unaffected
Young's Modulus:	Low Order
E' dynes/cm ²	High Order
E lb /inch ²	
	1000-lb General Purpose Bomb vs Concrete:
Density, gm/cc	there is a second of the second
	Height, It
Compressive Strength: Ib/inch ²	l'rials
e out office succession to the Mandalerson	Unaffected and 0.001 at ashields.
Vapor Pressure:	Low Order
°C mm Mercury	High Order
	and and a second s
	(0-1) (2 J) C (J) C (P) (P) (P) (P)
	Andrea as a second seco
	Volasility: 2 Volasility:

Fragmentation Test:		Shaped Charge Effectiveness, TNT $=$ 100:						
90 mm HE, M71 Projectile, Lot WC-91:		Glass Cones Steel Cones						
Density, gm/cc	1.58	Hole Volume						
Charge Wt, Ib	2.052	Hole Depth						
Total No. of Fragments:		Color: T.i.	sht vellow					
For TNT703For Subject HE864			200 /01100					
		Principal Uses: Boosters; ingredient of explo-						
3 inch HE, M42A1 Projectile, Lot KC-5:		sive mixtures,	letonators, and					
Density, gm/cc	Density, gm/cc 1.62		plasting caps					
Charge Wt, Ib	0.848							
Total No. of Fragments:	a na ma at	Method of Loading:	Pressed					
For TNT	514							
For Subject HE	605	Loading Density: gm/cc See helow						
Fragment Velocity: ft/sec	100 100 100 100 100 100 100 100 100 100	1966 In Bernd Conservation and he as	the same providing -					
At 9 ft At 25½ ft		Storage:	and the second second					
Density, gm/cc		Method	Davis					
		- Method	DLY					
Blast (Relative to TNT):		Hazard Class (Quantity-Distance)	Class 9					
Air: Peak Pressure		Compatibility Group Group L						
Impulse		Exudation Does not exude at 65°C						
Energy		A DE LA CERTRE EN EL CERTRE AN						
Air, Confined:		Loading Density: gm/cc						
Impulse		Cast 1.62 Pressed psi x 10 ³						
Under Water: Peak Pressure		0 3 5 10 12 0.9 1.40 1.47 1.57 1.6	2 15 20 50 1.63 1.67					
Impulse		and the second second second second second						
Energy		30 1.71	defensed III et					
Underground: Peak Pressure		Effect of Temperature on Rate of Detonation:	(j)					
Impulse		16 hms at Od						
Energy		Density, gm/cc 1.9 Rate, m/sec 71	52 1.53 50 7170					
		Real and the second states						

Tetryl

Preparation:

(Manufacture of Tetryl by Dinitromonomethylaniline Process, Wannamaker Chemical Co., Inc.)



To a solution of 202.5 gm dinitrochlorbenzene in 200 cc benzene, at 75° C with good agitation, in 15 to 20 minutes, add 112 gm of 30% aqueous monomethylamine. Then add 129 gm of 31% aqueous sodium hydroxide, in 15 to 20 minutes, at such a rate as to cause refluxing; continue agitation for 3 hours at 70° C. The mixture is concentrated to a liquid temperature of 101° - 102° C, cooled, filtered and the precipitate washed with distilled water until the washings give no test with silver nitrate, dried at 60° C (melting point 167.2° C).

The dinitromethylaniline is nitrated to tetryl by solution of it in 88% sulfuric acid (197 gm nitroaniline/1190 gm sulfuric) at 25° C, followed by addition of nitric acid. The process is carried out so that the water content remains at 16%. Solution (per 197 gm nitroaniline) requires 5 to 10 minutes, nitration, by addition of the sulfuric acid solution to nitric acid, about 1 hour at 30°C, plus 48 minutes at 50° to 55°C at the end. The mixture is then cooled to 20°C and filtered. The tetryl is dumped into 1 liter water, washed 2 or 3 times with 200 cc cold water, and then stirred 10 to 15 minutes at 50°C with 500 cc water, filtered warm and then washed with water until the washings are neutral to methyl orange. The tetryl dried to constant weight at 70°C weighs about 270 gm.

Tetryl filtered from an acid containing 87% sulfuric acid (or more) -13% water, at 40°C (or over) may fire in 30 minutes to 1 hour and 30 minutes, if not drowned in water. A safe nitration procedure, even on plant scale involves:

1. The concentration of sulfuric in the spent acid is maintained at a low level (approx 80/1.8/18.2 sulfuric/nitric/water).

- 2. Nitration maximum temperature is 50°C.
- 3. The slurry is cooled to 35°C before filtration.
- 4. Filtration time prior to drowning, is minimized (15 minutes maximum).

The crude tetryl produced is recrystallized to remove impurities and occluded acid and to control its granulation.

Tet	ryl

Sensitivi	ty of tetry	L electrost	tatic dischar	ge, joul	es; throu	igh 100 i	nesh: (i)		
Une Con	onfined fined		0.007 4.4						
Solubilit	y of tetryl,	, grams in	100 grams (%) of:					
Wa	ter	Car	rbon tetrachl	oride		Etl	ner	<u>95</u>	% Alcohol
°C	<u>%</u>	°c		1/2		°C	<u>%</u>	oC	%
0 20 40 80 100	0.0050 0.0075 0.0110 0.0810 0.184	0 20 40 60		0.007 0.015 0.058 0.154		0 10 20 30	0.188 0.330 0.418 0.493	0 10 20 30 50 75	0.320 0.425 0.563 0.76 1.72 5.33
Chl	oroform	Carbon	disulfide	Eth	ylene dic	hloride		Aceton	e
°C	2	<u>°C</u>	2	°C		1/2	0	c	<u>%</u>
0 20 40 60	0.28 0.39 1.20 2.65	0 10 20 30	0.009 0.015 0.021 0.030	25 75		4.5 45	2 3 4 5		75 95 116 138
Trichlo	roethylene	Ethyl a	icetate		Benzene	mpolip		Toluen	e
°C	<u>%</u>	°C	1/2	°C		1/2	0	c	<u>%</u>
0 20 40 60 80 86	0.07 0.12 0.26 0.67 1.50 1.76	20	~ 40	20 30 40 50		7.8 10.0 12.5 16.0	24	0	8.5
	Xylene			T	NT				
		°C	<u>%</u>		°c	1/2			
		20 30 40 50	3.3 4.4 5.4 6.0		80 100 120	82 149 645			

Origin:

Tetryl was first described in 1879 by Michler and Meyer (Ber 12, 1792), van Romburgh and Martens studied its properties and proved its structure (Rec trav chim 2, 108 (1883); 6, 215 (1887); and Ber 19, 2126 (1886)). Tetryl was not used as an explosive until World War I.

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Tetryl

Destruction by Chemical Decomposition:

Tetryl is decomposed by dissolving in 12 times its weight of a solution prepared from 1 part by weight of sodium sulfite $(Na_2SO_3, 7H_2O)$ in 4 parts water. The sulfite solution may be heated to $80^{\circ}C$ to facilitate decomposition of the Tetryl.

References: 73

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(b) Ph Naoum, Z ges Schiess --- Sprengstoffw, pp. 181, 229, 267 (27 June 1932).

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) L. C. Smith and S. R. Walton, <u>A Consideration of RDX/Wax Mixtures as a Substitute for</u> Tetryl in Boosters, NOL Memo 10,303; 15 June 1949.

(e) C. A. Taylor and Wm. H. Rinkenbach, "The Solubility of Trinitro-Phenylmethyl-Nitramine (Tetryl) in Organic Solvents," J Am Chem Soc 45, (1923) p. 104.

(f) E. Hutchinson, The Thermal Sensitiveness of Explosives. The Thermal Conductivity of Explosive Materials, AC 2861, First Report, August 1942.

(g) R. J. Finkelstein and G. Gamow, <u>Theory of the Detonation Process</u>, NAVORD Report No. 90-46, 20 April 1947.

(h) M. A. Cook and M. T. Abegg, "Isothermal Decomposition of Explosives," University of Utah, Ind Eng Chem 1090-1095 (June 1956).

(i) J. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

(j) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November 1956.

(k)	Also see	the fol	lowing	Picatinny	Arsenal	Techni	cal Rep	orts on	Tetryl:
0	<u>1</u>	2	3	<u>1</u>	<u>5</u>	6	<u>7</u>	8	<u>9</u>
30 600 770 810 1290 1350 1360 1450 1510 1510	11 361 381 621 861 1041 1131 1261 1311 1431 1471 1611 1651	132 582 832 882 1192 1352 1372 1402 1452 1592	453 493 823 833 1113 2053 2163 2233	84 144 294 314 694 7784 874 904 1134 1234 1264 2204	65 195 425 565 625 635 925 1145 1285 1405 1585 1885 1935 2105 2205	266 556 986 1086 1316 1316 1376 1416 1446 1446 1556 1636 1956	117 197 637 707 837 857 1047 1137 1287 137 1367 1437 1737 1797	28 438 628 708 788 838 1418 1788 1828 1838	129 179 319 609 709 849 999 1029 1209 1429 1489 1819 1969

73See footnote 1, page 10.

Composition:	Shered Thered	Molecular Weight:	274
Tetryl and here as a large	80	Oxygen Balance: CO ₂ % CO %	-52
TNT	20	Density: gm/cc Cast	1.51
		Melting Point: °C	68
C/H Ratio		Freezing Point: °C	aided to b
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	28	Boiling Point: °C	All and Bridgerick
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	9 17	Refractive Index, n ^D ₂₀ n ^D ₂₅	
Friction Pendulum Test:	NO IN DURINE .	Vacuum Stability Tast	State of the ball
Steel Shoe Fiber Shoe		cc/40 Hrs, at 90°C	
Rifle Bullet Impact Test: Trials		- 100°C 120°C	3.0 11+
Explosions 0		135°C 150°C	
Burned 0		200 Gram Bomb Sand Test:	ch o
		Sana, gm	54.0
Explosion Temperature: °C Seconds, 0.1 (no cap used)		Sensitivity to Initiation: Minimum Detonating Charge, gm	
Tanitas		Mercury Fulminate	0.22*
5 ignites 290		Lead Azide	0.17*
15		*Alternative initiating charges.	
20		Ballistic Mortar, % TNT:	mailagent
		Trauzi Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs		Plate Dent Test: Method	unter laure .
100°C Heat Test:		Condition	
% Loss, 1st 48 Hrs	0.1	Confined	
% Loss, 2nd 48 Hrs	0.5	Density, gm/cc	
Explosion in 100 Hrs	None	Brisance, % TNT	
Flammability Index: Will not continue	to burn	Detonation Rate: Confinement	Sec. 1
Hygroscopicity: %	0.02	Condition Charge Diameter, in.	
Volatility:		Density, gm/cc Rate, meters/second	

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Tetrytol, 80/20

Fragmentation Test:	Moteralas Weight	Shaped Charge Effectivenes	is, $TNT = 100$:
90 mm HE, M71 Project	ile, Lot WC-91:	Glass Cone	es Steel Cones
Density, gm/cc		Hole Volume	
Charge Wt, Ib	Develop grader (a	Hole Depth	
Total No. of Fragment	s: : : : : : : : : : : : : : : : : : :	Color:	Light yellow to buff
For TNT	and the second production of the second s		in the state of the
For Subject HE		Principal Uses: Burster	s, demolition blocks
3 inch HE, M42A1 Proje	ctile, Lot KC-5:		
Density, gm/cc	Representation Frances with		
Charge Wt, Ib			
Total No. of Fragments:		Method of Loading:	
For TNT			
For Subject HE		Loading Density: gm/cc	Police Steel
Fragment Velocity: ft/sec	(Januar)	n an	Rills Steller Inc. of Tak
At 9 ft At 25½ ft		Storage:	
Density, gm/cc		Method	Dry
Blast (Relative to TNT):	200 <u>Derri Jamb, Senti Yest.</u> Send, gia	Hazard Class (Quantity-	Distance) Class 9
Air:		Compatibility Group	Group I
Peak Pressure			Secondina 0.1 (no con unad
Impulse		Exudation	Exudes at 65°C
Energy			a alteration
17.07			
Air, Confined: Impulse			
		International states and the second	
Peak Pressure			
Impulse			
Energy		1 m 1 m 1 m 1 m 1 m 1 m 1 m 1 m 1 m 1 m	
		1.80	
Underground:		19.24	
Peak Pressure			
Impulse		and an experiment of the second se	
Energy		successfield and a state of the second	
		-	

Composition:	Molecular Weight:	270
Tetryl 75 INT 25	Oxygen Balance: CO ₂ % CO %	-54 -12
	Density: gm/cc Cast	1.59
	Melting Point: °C	68
C/H Ratio	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 28	Boiling Point: °C	W AM ASH E
Sample Wt 20 mgPicatinny Arsenal Apparatus, in.10Sample Wt, mg17	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	
Friction Pendulum Test: Steel Shoe Cracks	Vacuum Stability Test: cc/40 Hrs, at	ndriga pod all
Fiber Shoe Unaffected Rifle Bullet Impact Test: Trials % % Explosions 0	90°C - 100°C 120°C 135°C	3.0 11+
Partials 30 Burned 0 Unaffected 70	200 Gram Bomb Sand Test: Sand, gm	53.7
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 310 10	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide *Alternative initiating charges	0.23* 0.19*
15	Ballistic Mortar, % TNT: (a)	122
	Trauzl Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: (b) Method B	В
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Condition Cast Confined No Density, gm/cc 1.66 Brisance, % TNT 118	Cast Yes 1.62 114
Flammability Index: Will not continue to burn	- Detonation Rate: Confinement	None
Hygroscopicity: % 0.03	- Condition Charge Diameter, in.	Cast 1.0
Volatility:	Density, gm/cc Rate, meters/second	1.60 7385

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Tetrytol, 75/25

Fragmentation Test:	states and a plantation	Shaped Charge Effectiveness, $TNT=1$	IOO: mailting and it
90 mm HE, M71 Projectile, L Density, gm/cc Charge Wt. Ib	ot WC-91: 1.59 2.101	Glass Cones Steel Hole Volume 127 Hole Depth 120	Cones (d)
Total No. of Fragments:	702	Color: Light yell	ow to buff
For Subject HE	857	Principal Uses: Bursters, demoli	tion blocks
3 inch HE, M42A1 Projectile,	Lot KC-5:	n je na se na s Na se na s	Transferti Statisferi Disasteri Statisferi Disasteri Statisferi
Density, gm/cc Charge Wt, Ib	0.845	en in daar fi	Control and an operation of the second se
Total No. of Fragments: For TNT For Subject HE	514 591	Method of Loading:	Cast
	100	Loading Density: gm/cc	1.59
Fragment Velocity: ft/sec At 9 ft At 25½ ft		Storage:	naan aq at diis
Density, gm/cc		Method	Dry
Blast (Relative to TNT):	mp (end	Hazard Class (Quantity-Distance)	Class 9
Air: Peak Pressure Impulse Energy		Compatibility Group Exudation	Group I Exudes at 65 ⁰ C
Air, Confined: Impulse		Eutectic Temperature, ^o C: gm Tetryl/100 gm TNT 67.5°C	67.5 54 - 82
Under Water: Peak Pressure		Booster Sensitivity Test:	(c)
Impulse Energy		Condition Tetryl, gm Wax, in. for 50% Detonation	Cast 100 1.66
Underground: Peak Pressure		Density, gm/cc	1.66
Energy			
		n Andre Sterne Stern Sterne Sterne S	endersk, själleldenderer in en
		(*) () () () () () () () () ()	Regions applicing 19
			ty fillitiset e V

Composition:	Molecular Weight: 266	
% Tetryl 70	Oxygen Balance: -55 CO2 % -13	
Л.М.Т. ЗО	Density: gm/cc Cast 1.60	-
	Melting Point: °C 68	
C/H Ratio	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus cm 28	Boiling Point: °C	
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 11 Sample Wt, mg 18	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	
Friction Pendulum Test:Steel ShoeUnaffectedFiber ShoeUnaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C	
Rifle Bullet Impact Test: Trials		
Explosions 0 Partials 55	135°C 150°C	
Burned 0 Unaffected 45	200 Gram Bomb Sand Test: Sand, gm 53.2	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 416 1 387 5 Ignites 320 10 302	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.23* Lead Azide 0.22* Tetryl *Alternative initiating charges.	
15 289 20 275	Ballistic Mortar, % TNT: (a) 120	
20 -17	Trauzi Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test:(b)MethodB	
100°C Heat Test: % Loss, 1st 48 Hrs 0.1 % Loss, 2nd 48 Hrs 0.1 Explosion in 100 Hrs None	ConditionCastConfinedYesDensity, gm/cc1.60Brisance, % TNT117	
Flammability Index: Will not continue to bur	Detonation Rate: n Confinement None	
Hygroscopicity: % 0.02	Condition Cast Charge Diameter, in. 1.0	
Volatility:	Density, gm/cc1.60Rate, meters/second7340	

Fragmentation Test:		Shaped Charge Effectivene	ess, TNT = 100:
90 mm HE, M71 Projecti	le, Lot WC-91:	Glass Cor	nes Steel Cones
Density, gm/cc	1.60	Hole Volume	
Charge Wt, Ib	2.090	Hole Depth	
Total No. of Fragments	in an ing paint of	Color:	Light yellow to buff
For TNT	703		
For Subject HE	840	Principal lises Bungto	and demolition blocks
3 inch HE, M42A1 Projec	tile, Lot KC-5:	Frincipal Oses. Burste	rs, demotition blocks
Density, gm/cc	1.60		
Charge Wt, Ib	0.842		
			and the management
Total No. of Fragments:		Method of Loading:	Cast
For TNT	514		
For Subject HE	585	Loading Density: am/cc	1.60
Fragment Velocity: ft/sec	the second s		Wite Delive bearer Terre
At 9 ft			
At 251/2 ft		Storage:	Subalans .
Density, gm/cc		Method	Drv
	200 Gross Paush Louis Casts		(in the second se
Blast (Relative to TNT):	mg ,bhall	Hazard Class (Quantity	P-Distance) Class 9
Air:		Compatibility Group	Group I
Peak Pressure			
Impulse		Exudation	Exudes at 65 C
Energy			
sector and the sector s		10.2	
Air, Contined:	Spinista Markow, 95 THEF	a har e	
		and a second	
Under Water: Peak Pressure			
Impulse		an and the table table takes when the states of the state	
Energy			
		5.7	
Underground:		5.0	
Impulse		(inclusion)	
Fnerav			
Lifergy		munt skultskins s	
		inneteeranne ministration in the mission. Up the	
		CONTRACT OF CONTRACT.	
		n an	

Tetrytol, 65/35

Composition:	Molecular Weight: 264	ŧ.
% Tetryl 65 TNT 35	Oxygen Balance: -56 CO ₂ % -56 CO % -14	
	Density: gm/cc 1.60	
	Melting Point: °C 68	
C/H Ratio	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 28	Boiling Point: °C	
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 11 Sample Wt, mg 17	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	
Friction Pendulum Test:	Vacuum Stability Test:	
Steel ShoeCracksFiber ShoeUnaffected	cc/40 Hrs, at 90°C	
Rifle Bullet Impact Test: Trials Explosions 0 Partials 10	- 100°C 2.8 120°C 11+ 135°C 150°C	
Burned 0 Unaffected 90	200 Gram Bomb Sand Test: Sand, gm 52.6	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 325 10	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.23* Lead Azide 0.23* *Alternative initiating charges.	
15	Ballistic Mortar, % TNT:	
	Trauzi Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index: Will not continue to burn	Detonation Rate: Confinement None	
Hygroscopicity: % 0.02	- Condition Cast Charge Diameter, in. 1.0	
Volatility:	Density, gm/cc 1.60 Rate, meters/second 7310	

Fragmentation Test:	tennet minute to	Shaped Charge Effecti	veness, $TNT = 100$:
	C 01.	(Gloss	d) (e) Cones Steel Cones
90 mm HE, M/I Projectile, Lot W	1 61	Hole Volume	133 126
Density, gm/cc	2.010	Hole Volume	120 119
Charge Wt, Ib	2.010	Hole Depth	120 119
Total No. of Fragments:		Color:	
For TNT	703		Light yellow to buil
For Subject HE	856	Principal Uses: Bung	ters demolition blocks
3 inch HE, M42A1 Projectile, Lot K	(C-5: Manual and Manual	Burs	ters, demorration brocks
Density, gm/cc	1.60		
Charge Wt. Ib	0.845		
			an de shaal
Total No. of Fragments:		Method of Loading:	Cast
For TNT	514	-	
For Subject HE	585		*C77 . 10115
	1.01	Loading Density: gm/c	cc 1.60
Fragment Velocity: ft/sec	15-1961	a a contra	
At 9 ft			and a substitution of the
At 25½ ft		Storage:	
Density, gm/cc		Method	Dry
		Hozard Class (Quar	ntity-Distance) Class 9
Blast (Relative to TNT):			harded the C
Air:		Compatibility Group	Group I
Peak Pressure			~-O
Impulse		Exudation	Exudes at 65 C
Energy			
Air, Confined:			
Impulse			
Under Water:			
Peak Pressure			
Impulse			
Energy			
Underground:			
Peak Pressure			
Impulse			
Energy			

Compatibility with Metals:

Dry: Copper, brass, aluminum, magnesium, stainless steel, mild steel, mild steel coated with acid proof black paint and mild steel plated with copper, cadmium, zinc or nickel are unaffected. Magnesium-aluminum alloy is slightly affected.

<u>Wet:</u> Stainless steel and mild steel coated with acid-proof black paint are unaffected. Copper, brass, aluminum, magnesium, magnesium-aluminum alloy, mild steel and mild steel plated with cadmium, copper, zinc or nickel are slightly affected.

Preparation:

Tetrytols are manufactured by heating TNT in a melting kettle, equipped with a stirrer, until all the TNT is melted. The necessary amount oftetryl is added and heating and stirring are continued. The temperature is allowed to drop from 100°C until the mixture is of maximum viscosity suitable for pouring. Part of the tetryl dissolves in TNT forming a eutectic mixture which contains 55 percent tetryl. This mixture freezes at 67.5°C.

Origin:

Tetrytols were developed during World War II. The 70/30 tetryl/INT castable mixture is the most important in military applications.

References: 74

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(c) L. C. Smith and S. R. Walton, <u>A Consideration of RDX/Wax Mixtures as a Substitute for</u> Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(d) Eastern Laboratory, du Pont, <u>Investigation of Cavity Effect</u>, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W672-ORD-5723.

(e) Eastern Laboratory, du Pont, <u>Investigation of Cavity Effect</u>, Final Report, Eastern Lab, du Pont, 18 September 1943, NDRC Contract W-672-ORD-5723.

(f) Also see the following Picatinny Arsenal Technical Reports on Tetrytol:

0	<u>1</u>	2	3	5	6	<u>7</u>	8	2
1260 1360 1420 1500 1530	1291 1311 1451 1651 1951	1372	1193 1213 1363 1493	1285 1325 1885 2125	1376 1436 1466 1506	1477 1737 1797	1158 1388 1838	1379

74See footnote 1, page 10.

Composition:		Molecular Weight: $(C_7H_5N_3O_6)$	227			
C 37.0 CH H 2.2 O.N		Oxygen Balance: CO ₂ % CO%	-74 -25			
N 18.5	2	Density: gm/cc Crystal	1.65			
0 42.3	hilosita (Melting Point: °C	81			
C/H Ratio 0.549		Freezing Point: °C				
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	95-100+	Boiling Point: °C	"allistration"			
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	14-15 17	Refractive Index, n^D₂₀ α β Τ	1.5430 1.6742 1.717			
Friction Pendulum Test: Steel Shoe Una Fiber Shoe Una	affected	Vacuum Stability Test: cc/40 Hrs, at 90°C	interior Anterior Alterior			
Rifle Bullet Impact Test: Trials		100°C	0.10			
%		120°C	0.23			
Explosions 4		135°C	0.44			
Partials 0		150°C	0.65			
Burned 0 Unaffected 6		200 Gram Bomb Sand Test: Sand, gm	48.0			
Explosion Temperature: °C Seconds, 0.1 (no cap used) 570 1 520 5 Decomposes 475 10 465		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide *Alternative initiating charges	0.24* 0.27*			
20		Ballistic Mortar, % TNT:	St.d=100			
		Trauzi Test, % TNT:	Std=100			
75°C International Heat Test: % Loss in 48 Hrs	0.04	Plate Dent Test: (a) Method A A	B			
100°C Heat Test:	Adding in a second	Condition Cast Presse	d Cast			
% Loss, 1st 48 Hrs	0.2	Confined Yes Yes	No			
% Loss, 2nd 48 Hrs	0.2	Density, gm/cc 1.61 1.50	1.61			
Explosion in 100 Hrs	None	Brisance, % TNT 100 100	100			
Flammability Index: (b)	100	Detonation Rate: Confinement Unconfined	Unconfine			
Hygroscopicity: % 30°C. 90% RH	0.03	Condition Pressed	Cast			
		Charge Diameter, in. 1.0	1.0			
Volatility: 30°C	Nil	Rate, meters/second 6825	1,56 6640			

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Booster Sensitivity Test: Condition	(c) Pressed	Cast	Decomposition Equation: Oxygen, atoms/sec	(h) 10 ^{11.4}	(i) 10 ^{12.2}
Tetryl, gm	100	100	(Z/sec)	2)1)1	43.4
Wax, in. for 50% De	tonation 1.68	0.82	(ΔH, kcal/mol)	JH••	-J
Wax, am			Temperature Range, °C	275-310	238-277
Density, gm/cc	1.55	1.60	Phase	Liquid	Liquid
				a the way in the	SIT INST
Heat of: Combustion, cal/am	(d)	3620	Armor Plate Impact Test:		feel and
Explosion, cal/am		1080	60 mm Martes Brainstiles		(1)
Gas Volume, cc/an	n	730	50% Inert. Velocity. ft/	sec	>1100
Formation cal/am	an metering and	78.5	Aluminum Fineness		
Fusion col/om		22.34			
Temperature, °C		79	500-lb General Purpose Bo	mbs:	(j)
Specific Heat: cal/gm/°	°C		Plate Thickness, inches	Trials	% Inert
- o		0.309			
20		0.328	1	0	
50 80		0.373	11/4	0	
00		0.011	11/2	4	100
			13/4	4	50
Burning Rate:					
cm/sec			Bomb Drop Test:		
Thermal Conductivity: cal/sec/cm/°C	See next p	age.	T7, 2000-lb Semi-Armor-P	iercing Bomb	vs Concrete:
Coefficient of Expansion	. (b)	- Contraction of the	- Max Safe Drop, ft	50	00-6000
Linear, %/°C -40 ⁰ -40 ⁰	to 60°C 5.4 x to 60°C 6.7 x	10 ⁻⁵ (b)	500-Ib General Purpose Bo	No Seal	ete: Seal
Linear, %/°C -40° -40° Volume, %/°C 27°	to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x	10^{-5} (b) 10^{-5} (b)	500-1b General Purpose Bo	No Seal 4,000	ete: Seal 4-5,000
Linear, %/°C -40° -40° Volume, %/°C 27° 16°	to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3	10^{-5} (b) 10^{-5} (b) 10^{-5} (b) x 10^{-5} (n)	500-1b General Purpose Bo Height, ft Trials	<u>No Seal</u> 4,000 26	ete: <u>Seal</u> 4-5,000 20
Linear, %/°C -40° -40° Volume, %/°C 27° 16° Hardness, Mohs' Scale:	to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 (e)	10^{-5} (b) 10^{-5} (b) $x 10^{-5}$ (b) $x 10^{-5}$ (n) 1.4	500-1b General Purpose Bo Height, ft Trials Unaffected	mb vs Concr <u>No Seal</u> 4,000 26 24	ete: <u>Seal</u> 4-5,000 20 20
Linear, %/°C -40° -40° Volume, %/°C 27° 16° Hardness, Mohs' Scale:	to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 (e)	10^{-5} (b) 10^{-5} (b) $x 10^{-5}$ (b) $x 10^{-5}$ (n) 1.4	500-1b General Purpose Bo Height, ft Trials Unaffected Low Order	No Seal 4,000 26 24 2	ete: <u>Seal</u> 4-5,000 20 20 0
Linear, %/°C -40° -40° Volume, %/°C 27° 16° Hardness, Mohs' Scale: Young's Modulus:	to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 (e) (b)	10^{-5} (b) 10^{-5} (b) $x 10^{-5}$ (b) $x 10^{-5}$ (n) 1.4	 500-1b General Purpose Bac Height, ft Trials Unaffected Low Order High Order 	No Seal 4,000 26 24 2 0 0	ete: <u>Seal</u> 4-5,000 20 20 0 0
Linear, %/°C -40° -40° Volume, %/°C 27° 16° Hardness, Mohs' Scale: Young's Modulus: E', dynes/cm ²	to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 (e) (b)	$10^{-5} (b)$ $10^{-5} (b)$ $x 10^{-5} (n)$ 1.4 5.45×10^{10}	500-1b General Purpose Bo Height, ft Trials Unaffected Low Order High Order	No Seal 4,000 26 24 2 0 0	ete: <u>Seal</u> 4-5,000 20 20 0 0
Linear, %/°C -40° -40° Volume, %/°C 27° 16° Hardness, Mohs' Scale: Young's Modulus: E', dynes/cm ² E, Ib/inch ²	to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 (e) (b)	$10^{-5} (b)$ $10^{-5} (b)$ $x 10^{-5} (n)$ 1.4 5.45×10^{10} 0.79×10^{6}	500-1b General Purpose Ba Height, ft Trials Unaffected Low Order High Order 1000-1b General Purpose B	No Seal 4,000 26 24 2 0	ete: <u>Sea1</u> 4-5,000 20 20 0 0 0
Linear, %/°C -40° -40° Volume, %/°C 27° 16° Hardness, Mohs' Scale: Young's Modulus: E', dynes/cm ² E, Ib/inch ² Density, gm/cc	to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 (e) (b)	$10^{-5} (b)$ $10^{-5} (b)$ $x 10^{-5} (n)$ 1.4 5.45 x 10 ¹⁰ 0.79 x 10 ⁶ 161	 500-1b General Purpose Bar Height, ft Trials Unaffected Low Order High Order 1000-1b General Purpose Bar 	Mo Seal 4,000 26 24 2 0 mb vs Concr No Seal	ete: <u>Seal</u> 4-5,000 20 20 0 0 0 ete: <u>Seal</u> 5-222
Linear, %/°C -40° -40° Volume, %/°C 27° 16° Hardness, Mohs' Scale: Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc	to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 (e) (b)	$10^{-5} (b)$ $10^{-5} (b)$ $x 10^{-5} (n)$ 1.4 5.45×10^{10} 0.79×10^{6} 161	 500-1b General Purpose Bar Height, ft Trials Unaffected Low Order High Order 1000-1b General Purpose B Height, ft 	No Seal 4,000 26 24 2 0 0 comb vs Concr No No Seal 5,000 0	ete: <u>Seal</u> 4-5,000 20 0 0 0 ete: <u>Seal</u> 5,000 0
Linear, %/°C -40° -40° Volume, %/°C 27° 16° Hardness, Mohs' Scale: Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc	to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 (e) (b)	$ \begin{array}{c} 10^{-5} (b) \\ 10^{-5} (b) \\ x 10^{-5} (b) \\ x 10^{-5} (b) \\ x 10^{-5} (c) \\ 1.4 $ 5.45 x 10 ¹⁰ 0.79 x 10 ⁶ 161 0-14000 1.62	 500-1b General Purpose Back Height, ft Trials Unaffected Low Order High Order 1000-1b General Purpose Back Height, ft Trials 	No Seal 4,000 26 24 2 0 0 omb vs Concr No No Seal 5,000 21	ete: <u>Seal</u> 4-5,000 20 20 0 0 0 0 ete: <u>Seal</u> 5,000 26 22
Linear, %/°C -40 ^o -40 ^o Volume, %/°C 27 ^o 16 ^o Hardness, Mohs' Scale: Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc	to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 (e) (b)	$10^{-5} (b)$ $10^{-5} (b)$ $x 10^{-5} (n)$ 1.4 5.45×10^{10} 0.79×10^{6} 161 $0-14000$ 1.62	 500-1b General Purpose Back Height, ft Trials Unaffected Low Order High Order 1000-1b General Purpose Back Height, ft Trials Unaffected 	No Seal 4,000 26 24 2 0 0 comb vs Concr No No Seal 5,000 21 18 2	ete: <u>Seal</u> 4-5,000 20 20 0 0 0 0 ete: <u>Seal</u> 5,000 26 22
Linear, %/°C -40° -40° Volume, %/°C 27° 16° Hardness, Mohs' Scale: Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc Compressive Strength: I Density, gm/cc	to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 (e) (b)	$ \begin{array}{c} 10^{-5} (b) \\ 10^{-5} (b) \\ x 10^{-5} (b) \\ x 10^{-5} (b) \\ x 10^{-5} (c) \\ 1.4 $ 5.45 x 10 ¹⁰ 0.79 x 10 ⁶ 161 0-14000 1.62 (f)	 500-1b General Purpose Back Height, ft Trials Unaffected Low Order High Order 1000-1b General Purpose Back Height, ft Trials Unaffected Low Order 	No Seal 4,000 26 24 2 0 0 comb vs Concr No Seal 5,000 21 18 0	ete: <u>Seal</u> 4-5,000 20 20 0 0 0 ete: <u>Seal</u> 5,000 26 22 0
Linear, %/°C -40° -40° Volume, %/°C 27° 16° Hardness, Mohs' Scale: Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc Compressive Strength: I Density, gm/cc	to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 (e) (b) b/inch ² 1380	$ \begin{array}{c} 10^{-5} (b) \\ 10^{-5} (b) \\ x 10^{-5} (b) \\ x 10^{-5} (b) \\ x 10^{-5} (c) \\ 1.4 \end{array} $ 5.45 x 10 ¹⁰ 0.79 x 10 ⁶ 161 0-14000 1.62 (f)	 500-1b General Purpose Back Height, ft Trials Unaffected Low Order High Order 1000-1b General Purpose Back Height, ft Trials Unaffected Low Order Height, ft Trials Unaffected Low Order High Order 	No Seal 4,000 26 24 2 0 0 comb vs Concr No No Seal 5,000 21 18 0 3 3	ete: <u>Seal</u> 4-5,000 20 20 0 0 0 0 ete: <u>Seal</u> 5,000 26 22 0 4
Linear, %/°C -40° -40° Volume, %/°C 27° 16° Hardness, Mohs' Scale: Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc Compressive Strength: I Density, gm/cc Vapor Pressure: °C 80 85	to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 (e) (b) b/inch ² 1380 mm Mercury 0.042 0.053	$ \begin{array}{c} 10^{-5} (b) \\ 10^{-5} (b) \\ x 10^{-5} (b) \\ x 10^{-5} (b) \\ x 10^{-5} (b) \\ x 10^{-5} (c) \\ 1.4 \end{array} $ 5.45 x 10 ¹⁰ 0.79 x 10 ⁶ 161 0-14000 1.62 (f)	500-1b General Purpose Ba Height, ft Trials Unaffected Low Order High Order 1000-1b General Purpose B Height, ft Trials Unaffected Low Order High Order	No Seal 4,000 26 24 2 0 26 24 2 0 0 somb vs Concr No Seal 5,000 21 18 0 3 3	ete: <u>Seal</u> 4-5,000 20 20 0 0 0 0 ete: <u>Seal</u> 5,000 26 22 0 4
Linear, %/°C -40° -40° Volume, %/°C 27° 16° Hardness, Mohs' Scale: Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc Compressive Strength: I Density, gm/cc Vapor Pressure: °C 1 80 85 90	to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 (e) (b) b/inch ² 1380 mm Mercury 0.042 0.053 0.067	$ \begin{array}{c} 10^{-5} (b) \\ 10^{-5} (b) \\ x 10^{-5} (b) \\ x 10^{-5} (b) \\ x 10^{-5} (c) \\ 1.4 \end{array} $ 5.45 x 10 ¹⁰ 0.79 x 10 ⁶ 161 0-14000 1.62 (f)	500-1b General Purpose Ba Height, ft Trials Unaffected Low Order High Order 1000-1b General Purpose B Height, ft Trials Unaffected Low Order High Order	No Seal 4,000 26 24 2 0 0 comb vs Concr No Seal 5,000 21 18 0 3	ete: <u>Seal</u> 4-5,000 20 20 0 0 0 ete: <u>Seal</u> 5,000 26 22 0 4
Linear, %/°C -40° -40° Volume, %/°C 27° 16° Hardness, Mohs' Scale: Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc Compressive Strength: I Density, gm/cc Vapor Pressure: °C 80 85 90 95	to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 (e) (b) b/inch ² 1380 mm Mercury 0.042 0.053 0.067 0.085	$ \begin{array}{c} 10^{-5} & (b) \\ 10^{-5} & (b) \\ x & 10^{-5} & (b) \\ x & 10^{-5} & (b) \\ x & 10^{-5} & (b) \\ 1.4 \end{array} $ $ \begin{array}{c} 5.45 \times 10^{10} \\ 0.79 \times 10^{6} \\ 161 \end{array} $ $ \begin{array}{c} 0 -14000 \\ 1.62 \end{array} $ $ \begin{array}{c} (f) \end{array} $	500-1b General Purpose Ba Height, ft Trials Unaffected Low Order High Order 1000-1b General Purpose B Height, ft Trials Unaffected Low Order High Order	No Seal 4,000 26 24 2 0 0 comb vs Concr No Seal 5,000 21 18 0 3	ete: <u>Seal</u> 4-5,000 20 20 0 0 ete: <u>Seal</u> 5,000 26 22 0 4

Fragmentation Test:	Paranteritedian - Corport, anno	Shaped Charge Effectiveness, TNT $=$ 100:
90 mm HE, M71 Projectile, Lot WC-91	Research Miller Conf	Glass Cones Steel Cones
Density, gm/cc	1.60	Hole Volume 100 100
Charge Wt, Ib	2.104	Hole Depth 100 100
Total No. of Fragments:		
For TNT	703	Color: Light yellow
For Subject HE	703	Principal Uses: GP bombs, HE projectiles,
3 inch HE, M42A1 Projectile, Lot KC-5:		demolition charges, depth charges,
Density, am/cc	1.60	grenades, propellant compositions
Charge Wt Ib	0.848	A North Annual Company
	100 de Dat	 Manual Manual M Manual Manual Manu Manual Manual Manua Manual Manual Manu
Total No. of Fragments:		Mathad of Loading,] Coat
For TNT	514	2. Pressed
For Subject HE	514	
		Loading Density: gm/cc See below
Fragment Velocity: ft/sec	(k)	- +++ . ()
At 9 ft	2600	
At 251/2 ft	2360	Storage:
Density, gm/cc	1.58	The Part of the Pa
		Method Dry
Blast (Relative to TNT):	a-osur 'ya	Hazard Class (Quantity-Distance) Class 9
Air:		Compatibility Group Group I
Peak Pressure	100	faufflutting of frequencies
Impulse the second s	100	Exudation None at 65°C
Energy	100	
prove estimates and the second		
Air, Confined:	dar of .	Loading Density: gm/cc
Impulse	100	1. Cast 1.58-1.59 2. Pressed psi x 10 ³
Under Water		2 5 10 15 00 50
Peak Pressure	100	1.35 1.40 1.45 1.52 1.55 1.59 1.6
Impulse	100	Thermal Conductivity:
Energy	100	cal/sec/cm/°C
Underground:		Density 1.19 gm/cc (g) 5.28 x 10 1
Peak Pressure	100	1.51 gm/cc (g) 7.12 x 10^{-4}
Impulse	100	$1.54 \text{ gm/cc} (b) 5.6 \times 10^{-4}$
Energy	100	Vigeosity poises:
		100°C 0.139
		Bulk Modulus at RoomTemperature $(25^{\circ}-30^{\circ}C)$:Dynes/cm ² x 10 ⁻¹⁰ 2.92
		Density, gm/cc 1.56

Effect of Temperature on Rate	of Detonat	tion: (1)				
Temperature of Charge, ^O C	-54	21	60	60		
Hours at Temperature	16	16	24	72		
Density, gm/cc	1.63	1.62	1.64	1.64		
Rate, meters/second	6700	6820	6770	6510		
Sensitivity to Electrostatic	Discharge,	Joules; 1	hrough 1	.00 Mesh:		
Unconfined Confined	0.06 4.4					
Impact Sensitivity versus Tem	perature:					
Picatinny Arsenal Apparatu	s, 2 kg wt	, inches:				
<u>°c</u> <u>i</u>	nches					
-40 Room 80 90 105-110	17 14 7 3 2 (5 exp	1 in 20 t:	rials)			
Impact Sensitivity versus Loa	ding Metho	d, Large	Impact Ap	pparatus,	Inches:	
Pressed at 1.60 gm/cc Cast at 1.60 gm/cc	70 26					
Rifle Bullet Impact Sensitivi	ty versus	Temperatu	re, Confi	inement:		
Standard Iron Bomb:		R Tem	oom perature		105 ⁰ to 1	10 ⁰ C
No Air Space Trials Explosions		l very	10 low orde	er	10 7	
Air Space Trials Explosions			10 0		10 0	
Tin or Cardboard Bombs:						
With or Without Air Spac Trials Explosions	ce		10 0		10 0	

Explosion Temperature versus INT Initial Temperature:

INT Temperature, Initial	Explosion Temperature	e, ⁰c
Room 105 ⁰ -100 ⁰ C	470 (Decomposes) 480 (Decomposes)	
Explosion Temperature versus Confinement	, ^o c:	

Unconf	ine	a		Decomposes	470
Sealed	in	glass	capillary	Explodes	320-335

Viscosity at 80.5°C:

Viscosity, X, cp log X = 0.046 S + 1.26 S = % solid in slurry Particle size effect, small

Density, gm/cc:

°c	State	gm/cc
27 to 70	Flaked	1.65
80	Flaked	1.64
82	Liquid	1.48
87	Liquid	1.48
95	Liquid	1.47

Solubility of TNT, gm/100 gm (%), in: (f)

Wa	ter	Ace	tone	Be	enzene	To:	luene	
°C	%	°c	Z	<u>°C</u>	<u>%</u>	°C	<u>%</u>	
0 20 40 60	0.0100 0.0130 0.0285 0.0675	0 20 40 60	57 109 228 600	0 20 40 60 80	13 67 180 478 72000	0 20 40 60 80	28 55 130 367 >1700	

C	arbon					
tetra	chloride	Etl	ner	Chloro	oform	
°C	<u>%</u>	°C	%	°c	<u>%</u>	
0 0 40 60 70 75	0.20 0.65 1.75 6.90 17.34 24.35	0 20	1.73 3.29	0 20 40 60	6 19 66 302	

%

3.5

60

Trichloroethylene

°C

25

55

Pyri	dine	Methyl	. acetate	Eth	nylene hloride	A-Et ethyl-	hoxy- acetate
°c	1/2	°c	<u>%</u>	°C	<u>%</u>	°C	_%
20 40 60 70	140 250 640 1250	20 40 50	73 135 280	20 40 60	34 123 460	20 40 50	29.5 49 96
Tetrac	chloro- nane	Ar	niline	Ison alo	propyl cohol	Etha	anol
°c	1/2	°c	1/2	°c	16	°c	<u>%</u>
20 40 50	18 50 100	10 30 50 70 80	6.1 11.5 29 74 130	20 40 50	0.76 1.96 2.95	0 20 40 60 70	0.62 1.25 2.85 8.4 15
Isobu	utyl alcol	nol		Carbon dis	ulfide	Chlorob	penzene
°c		<u>%</u>		°c	<u>%</u>	<u>°C</u>	<u>%</u>
0 20 40 50		0.20 0.61 1.41 2.35		0 20 40	0.14 0.44 1.4	20 30 40 50	3 5 51 79 116

Preparation:

.

(AC 7258, 7259, 7260 - Nitration Kinetics) (Chemistry of Powder and Explosives, Davis)



In older processes trinitrotoluene (TNT) was slowly and laboriously nitrated in three stages using successively stronger acids. Today, however, a single stage nitration is possible, in a short time (less than one hour) producing TNT at a cost of a little less than $6\phi/lb$. In England, a two stage continuous process was developed during World War II; in the first counter current stage, toluene was nitrated to the mono stage mononitrotoluene (MNT); in the second stage, also counter current, MNB was nitrated to TNT.

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TNT (Trinitrotoluene)

It was the British work, on the kinetics of nitration of toluene to TNT, that first pointed out the basic importance to nitration processes of the nitroxyl ion (NO_2+) , on the one hand, and the role of the bisulfate ion (HSO_4-) and unionized sulfuric acid on the other. These concepts were successful in explaining the maximum in nitration rate occurring at a sulfuric acid content of 92%. This work, for instance, leads to the following equation for the rate of formation of TNT from DNT:

$\frac{d (\text{INT})}{dt} = K (\text{NO}_2^+) [K' (\text{HSO}_4^-) + K'' (\text{H}_2\text{SO}_4)] (\text{DNT})$

<u>Three Stage Process:</u> Toluene (100 gm) is nitrated to the mono derivative by slowly adding a mixture of 294 gm sulfuric acid (sp gr 1.84) and 147 gm nitric acid (sp gr 1.42) to it at $30^{\circ}-40^{\circ}$ C, with good agitation. Acid addition requires 1-1.5 hour, and stirring at $30^{\circ}-40^{\circ}$ C is continued 30 minutes longer. The mixture is cooled and the lower layer of spent acid drawn off.

Half the crude mono is dissolved in 109 gm sulfuric acid (sp gr 1.84) with cooling, the solution heated to 50° C and a mixture of 54.5 gm nitric acid (sp gr 1.50) and 54.5 gm sulfuric acid (sp gr 1.84) added, under agitation, at such a rate that the temperature is maintained between 90° and 100° C. Acid addition requires 1 hour, and stirring at 90° - 100° C is continued 2 more hours.

While the dinitration mixture is still at 90° C, 145 gm fuming sulfuric acid (oleum containing 15% free SO₃) is added slowly. A mixed acid of 92.5 gm each nitric acid (sp gr 1.50) and 15% oleum is slowly added, under good agitation at 100° -115°C over $1\frac{1}{2}$ -2 hours. The mixture is stirred at 100° -115°C for 2 more hours, cooled, filtered, and the TNT cake broken up and washed with water. The TNT is washed 3-4 times with hot water (85° -95°C) with good agitation. The product can be purified either by recrystallization from alcohol or by washing it with 5 times its weight of 5% sodium bisulfite solution at 90° C for $\frac{1}{2}$ hour with vigorous stirring, washing with hot water until the washings are colorless, and cooling slowly with stirring to granulate the product.

Origin:

TNT was first prepared in 1863 by Wilbrand (Ann 128, 178), later by Beilstein and Kuhlberg (Ber 3, 202 (1870) and also Tiemann (Ber 3, 217 (1870), each using different methods of starting materials. It was nearly 30 years later when Hausermann undertook its manufacture on an industrial scale (Z angew Chem, 1891, p. 508; J Chem Ind, 1891, p. 1028). After 1901 TNT began to be used extensively as a military explosive and Germany became the first nation to adopt it as a standard shell filler (1902-1904). During World War I all the major powers of the world were using TNT, with the quantity used limited only by the available supply of toluene. Prior to World War II the development of synthetic toluene from petroleum made available in the United States, an almost unlimited supply of this raw material. Because of the general suitability of TNT for melt-loading and its extensive use in binary and ternary explosive mixtures, TNT is considered the most important military explosive known today.

Destruction by Chemical Decomposition:

TNT is decomposed by adding it slowly, while stirring, to 30 times its weight of a solution prepared by dissolving 1 part of sodium sulfide (Na₂S·9H₂O) in 6 parts of water.

References:75

(a) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

75See footnote 1, page 10.

(b) Philip C. Keenan and Dorothy Pipes, <u>Table of Military High Explosives</u>, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(c) L. C. Smith and S. R. Walton, <u>A Consideration of RDX/Wax Mixtures as a Substitute for</u> Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(d) L. C. Smith and E. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report No. 5746, 27 December 1945.

(e) Report AC-2587.

(f) International Critical Tables and various other sources in the open literature.

(g) E. Hutchinson, The Thermal Sensitiveness of Explosives. The Thermal Conductivity of Explosive Materials, AC-2861, First Report, August 1942.

(h) A. J. B. Robertson, Trans Farad Society, 44, 977 (1948).

(i) M. A. Cook and M. T. Abegg, "Isothermal Decomposition of Explosives," University of Utah, Ind Eng Chem (June 1956), pp. 1090-1095.

(j) Committee of Div 2 and 8, NDRC, <u>Report on HBX and Tritonal</u>, OSRD No. 5406, 31 July 1945.

(k) R. W. Drake, Fragment Velocity and Panel Penetration of Several Explosives in Simulated Shells, OSRD Report No. 5622, 2 January 1946.

(1) W. F. McGarry and T. W. Stevens, <u>Detonation Rates of the More Important Military</u> Explosives at Several Different Temperatures, PATR No. 2383, November 1956.

(m) W. S. Cramer, Bulk Compressibility Data on Several High Explosives, NAVORD Report No. 4380, 15 September 1956.

(n) Mantrov, Journal of Chemical Industry (Russia) 6, 1929, pp. 1686-1688.

(o) Also see the following Picatinny Arsenal Technical Reports on INT:

<u>o</u>	1	2	<u>3</u>	<u>2</u> +	5	6	<u>7</u>	8	2
10 30 240 350 630 760 810 1120 1140 1260 1270 1360 1400 1400 1460	291 551 731 861 901 971 1041 1121 1311 1391 1451 1451 1451 1821	132 582 782 892 972 1072 1182 1292 1342 1352 1352 1352 1352 1402 1452 1452	43 83 273 513 643 673 743 863 1023 1123 1123 1243 1243 1323	364 694 874 904 1094 1124 1284 1294 1304 1314 1344 1344 1414 1454	65 195 425 555 695 735 805 975 1145 1285 1305 1305 1315 1395 1425	86 266 556 956 1046 1276 1376 1446 1476 1456 1456 1636 1756	47 87 507 527 597 707 807 817 837 1107 1147 1247 1307 1417 1427	118 288 638 738 768 838 1088 1088 1128 1128 1148 1158 1158 1198 1228 1258 1308	99 249 269 319 389 499 709 739 779 799 889 929 929 939 1099 1129

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<u>o</u>	2	<u>3</u>	<u>4</u>	5	6	<u>7</u>	8	<u>9</u>
1530 1540 1550 1730 2010 2100 2160	1492 1562 1582 1712 1862	137 149 155 163 169 182 206 216	3 152 3 154 3 156 3 160 3 167 3 175 3 192 3 206 221	4 143 4 144 4 149 4 151 4 153 4 158 4 160 4 163 4 166 196 171 188 212 217	5 1956 5 2216 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	6 1437 1497 1537 1547 1557 1557 1577 1597 1677 1737 1797 1827 1847 2007 2147 2167	1318 1338 1388 1418 1428 1578 1618 1688 1728 1828 1838 1858 2008 2138 2168	1139 1179 1199 1259 1289 1339 1369 1379 1419 1429 1469 1489 1529 1549 1629 1689 1709 1729 1749 1809 1819 1879
								1949 2159 2179
								2113

Composition:	Herenauth	Molecular Weight:	97
%	Same and	Oxvaen Balance:	and the second
RDX	42	CO2 %	-55
गगुरम्	40	CO %	-26
Δ]	18	Density: gm/cc Cast	1.76-1.81
Aruminum	10	Melting Point: °C	
C/H Ratio		Freezing Point: °C	a sentrading 25°
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C	
Bureau of Mines Apparatus, cm Sample Wt 20 mg	42	Refractive Index. nº	and a subserver of the
Picatinny Arsenal Apparatus, in.	9		
Sample Wt, mg	15	Π ₂₅	
		n ₃₀	Security Here Free
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe		cc/40 Hrs, at	
Fiber Shoe		90°C	
Diffe Bullet Impact Tests Trials	1.4	100°C	
KITIE BUIIET IMPACT LEST: I FIGIS		120°C	1.0
Explosions 20		135°C	
Partials 80		150°C	
Burned 0		200 Gram Bomb Sand Test:	
Unoffected 0		Sand, gm	59.5
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 260 10	ning synw an di dina Janahi	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	0.18
15		Ballistic Mortar, % TNT: (a)	138
20	nil unit	Trauzi Test, % TNT: (b)	164
75°C International Heat Test: % Loss in 48 Hrs	O-date	Plate Dent Test: (c) Method	В
100°C Heat Test:		Condition	Cast
% Loss. 1st 48 Hrs	0.00	Confined	No
% Loss, 2nd 48 Hrs	0.10	Density, gm/cc	1.83
Explosion in 100 Hrs	None	Brisance, % TNT	120
Flammability Index:	196	Detonation Rate: (d) Confinement	None
0		- Condition	Cast
Hygroscopicity: % 30°C, 90% RH	0.00	Charge Diameter, in.	1.0
		Density, gm/cc	1.81
Volatility:		Rate, meters/second	7495

Torpex

Booster Sensitivity Test:	(c) Pressed	Cast	Decomposition Equation:	
Tetryl am	10	5	(Z/sec)	
Wax in for 50% Datana	tion	00. 1	Heat, kilocalorie/mole	
Wax, m. for 50 % Detond			(ΔH, kcal/mol)	
Density em (cc	1 6)	1 81	Dhase	
Density, gm/cc	1.04	1.01	Phase	
Heat of:	(a)	2710	Armor Plate Impact Test:	
Evaluation, cal/gm		3140		
Gas Volume, cc/gm		1000	60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec	(a) 185
Formation, cal/gm			Aluminum Fineness	
rusion, cui/gm	in .		500-ib General Purpose Bombs:	
Specific Heat: cal/gm/°C	(b)			
At -5°C	pippi	0.22	Plate Thickness, inches	
Density, gm/cc		1.82	1	
At 15°C		0.24	11/4	
		0.00] ½	
			134	
Burning Rate:				
cm/sec			Bomb Drop Test:	1 to imp ¹⁴
Thermal Conductivity:	(b)	0.7. 10-4	T7, 2000-lb Semi-Armor-Piercing Bor	nb vs Concrete:
Density, gm/cc		1.82		
Coefficient of Expansion:	ad2 m. m. an	C meminal	Max Safe Drop, ft	
Linear, %/°C -73 to	75°C 4.7 x	10 ⁻⁵ (b)	500-lb General Purpose Bomb vs Cor	ncrete:
Volume, %/°C			Orani institution -	
			Height, ft	
		'eds'	Height, ft Trials	
Hardness, Mohs' Scale:	- 1917	Toto: Toto: Toto:	Height, ft Trials Unaffected	
Hardness, Mohs' Scale:	4.5	Tobal Behistle V V	Height, ft Trials Unaffected Low Order	
Hardness, Mohs' Scale: Young's Modulus: E', dynes/cm ²	(b) 9•5	3 x 10 ¹⁰	Height, ft Trials Unaffected Low Order High Order	
Hardness, Mohs' Scale: Young's Modulus: E', dynes/cm ² E, lb/inch ²	(b) 9.5 1.3	3 x 10 ¹⁰ 8 x 10 ⁶	Height, ft Trials Unaffected Low Order High Order	6) 9 (
Hardness, Mohs' Scale: Young's Modulus: E', dynes/cm ² E, Ib/inch ² Density, gm/cc	(b) 9.5 1.3	3×10^{10} 8×10^{6} 1.77	Height, ft Trials Unaffected Low Order High Order 1000-Ib General Purpose Bomb vs Cor	icrete:
Hardness, Mohs' Scale: Young's Modulus: E', dynes/cm ² E, Ib/inch ² Density, gm/cc	(b) 9.5 1.3	3 x 10 ¹⁰ 8 x 10 ⁶ 1.77	Height, ft Trials Unaffected Low Order High Order 1000-Ib General Purpose Bomb vs Cor Height, ft	icrete:
Hardness, Mohs' Scale: Young's Modulus: E', dynes/cm ² E, Ib/inch ² Density, gm/cc Compressive Strength: Ib/inc	(b) 9.5 1.3 h ² (b) 21	3 x 10 ¹⁰ 8 x 10 ⁶ 1.77 00-2300	Height, ft Trials Unaffected Low Order High Order 1000-Ib General Purpose Bomb vs Cor Height, ft Trials	icrete:
Hardness, Mohs' Scale: Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc Compressive Strength: lb/inc Density, gm/cc	(b) 9.5 1.3 h ² (b) 21	3 x 10 ¹⁰ 8 x 10 ⁶ 1.77 00-2300 1.77	Height, ft Trials Unaffected Low Order High Order 1000-Ib General Purpose Bomb vs Cor Height, ft Trials Unaffected	in and of the second of the second of the second of the second of the second of
Hardness, Mohs' Scale: Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc Compressive Strength: lb/inc Density, gm/cc Vapor Pressure:	(b) 9.5 1.3 h² (b) 21	3 x 10 ¹⁰ 8 x 10 ⁶ 1.77 00-2300 1.77	Height, ft Trials Unaffected Low Order High Order 1000-Ib General Purpose Bomb vs Cor Height, ft Trials Unaffected Low Order	icrete:
Hardness, Mohs' Scale: Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc Compressive Strength: lb/inc Density, gm/cc Vapor Pressure: °C mm N	(b) 9.5 1.3 h ² (b) 21 Nercury	3 x 10 ¹⁰ 8 x 10 ⁶ 1.77 00-2300 1.77	Height, ft Trials Unaffected Low Order High Order 1000-Ib General Purpose Bomb vs Cor Height, ft Trials Unaffected Low Order High Order	ncrete:
Hardness, Mohs' Scale: Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc Compressive Strength: lb/inc Density, gm/cc Vapor Pressure: °C mm N	(b) 9.5 1.3 h ² (b) 21 Aercury	3 x 10 ¹⁰ 8 x 10 ⁶ 1.77 00-2300 1.77	Height, ft Trials Unaffected Low Order High Order 1000-Ib General Purpose Bomb vs Cor Height, ft Trials Unaffected Low Order High Order	And and a financial and a fina
Hardness, Mohs' Scale: Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc Compressive Strength: lb/inc Density, gm/cc Vapor Pressure: °C mm N	(b) 9.5 1.3 h ² (b) 21 Aercury	3 x 10 ¹⁰ 8 x 10 ⁶ 1.77 00-2300 1.77	Height, ft Trials Unaffected Low Order High Order 1000-Ib General Purpose Bomb vs Cor Height, ft Trials Unaffected Low Order High Order	And and a second s

Fragmentation Test:		Shaped Charge Effectiveness, TNT = 100: 50/36.5/13.5 Glass Cones Steel Cones		
90 mm HE, M71 Projectile, Lot WC-91:				
Density, gm/cc	1.75	Hole Volume 150 145		
Charge Wt, Ib	2.316	Hole Depth 127 131		
Total No. of Fragments:	and the	Color:	Gray	
For TNT	703			
For Subject HE	891	Principal Uses: Depth charges, bo	mbs	
3 inch HE, M42A1 Projectile, Lot KC-5:				
Density, gm/cc	1.79	real ground for all up a lost states and		
Charge Wt, Ib	0.940	A MARTINE CONTRACTOR		
Total No. of Fragments:		Method of Loading:	Cast	
For TNT	514			
For Subject HE	647	Loading Density: gm/cc	1.76-1.81	
Free and Valacian (t/soc				
At 9 ft At 251/2 ft	2960 2800	Storage:	tan animati	
Density, gm/cc		Method	Dry	
Blast (Relative to TNT):	(e)	Hazard Class (Quantity-Distance)	Class 9	
Aim		Compatibility Group	Group I	
Peak Pressure	122	at antibuct () is include a provide by		
Impulse	125	Exudation		
Energy	146	1 100 100 100 100 100 100 100 100 100 1	<u>na dala da Dilad</u>	
poly devices and the provide section of the		Effect of Temperature on		
Air, Confined:	116	Impact Sensitivity:		
inpulse		Temp. PA Impact Test		
Under Water:	116	OC 2 Kg Wt, inches		
Peak Pressure	TTO	25 15		
Impulse	127	32 7		
Energy	123	104 8		
Underground: Peak Pressure		Viscosity, poises:		
Impulse		Temp, 83 ^o C	4.5	
Energy		95°0	2.3	
		and and a state of the second seco		
		the second se		

Torpex

Preparation:

Torpex is manufactured by heating TNT to approximately 100°C in a steam-jacketed kettle equipped with a stirrer. Water wet RDX is added slowly to the molten TNT, while mixing and heating, until all the water is evaporated. Aluminum is added and the mixture is stirred until uniform. The mixture is cooled, with continued stirring, until it is suitable for pouring. Torpex can also be made by adding the calculated amount of TNT to Composition B to maintain the desired proportion of RDX/TNT, heating and stirring, and adding 18 percent of aluminum to complete the mixture.

Origin:

Torpex, a castable high explosive, was developed in England during World War II for use as a filler in warheads, mines and depth bombs. Several variations in the composition of torpex have been evaluated but the following are those used in service munitions:

	Torpex 2 unwaxed	Torpex 2 waxed	Torpex 3	
	(a)	(b)	(c)	
RDX, % TNT, % Aluminum, % Wax, % Calcium chloride, %	42 40 18	41.6 39.7 18.0 0.7	41.4 39.5 17.9 0.7 0.5	

(a) Made from Composition B-2 or 60/40 Cyclotol.

(b) Made by the addition of aluminum to Composition B.

(c) Made by the addition of calcium chloride to Torpex 2.

Wax has the undesirable effect of (1) tending to coagulate the aluminum, thus giving a less homogeneous and more viscous product, (2) lowering the density of the cast explosive from 1.72-1.75 to 1.66-1.70 for waxed torpex, and (3) lowering the compressive strength from 3700 psi to 1970 psi for waxed torpex. However, wax is used in service torpex for reasons of safety, since there is evidence that its presence lowers the sensitivity of the explosive to impact as measured by laboratory drop tests and bullet sensitivity tests of small charges (Bureau of Ord Res Memo Rpt No. 24, January 1945).

References: 76

(a) Committee of Div 2 and 8, NDRC, <u>Report on HBX and Tritonal</u>, OSRD No. 5406, 31 July 1945.

(b) Philip C. Keenan and Dorothy C. Pipes, <u>Table of Military High Explosives</u>, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

L. C. Smith and E. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report No. 5746, 27 December 1945.

⁷⁶See footnote 1, page 10.

Torpex

(d) G. H No. 1219, 22 M. D No. 5611, 15	. Messerly February . Hurwitz, January 1	7, <u>The Rate</u> 1943. <u>The Rate (</u> 946.	of Detona of Detonat:	tion of Va ion of Var	rious Explo	sive Comp nds and M	ixtures, 0	D Report SRD Report
(e) W. R	. Tomlinso	m, Jr., <u>Ble</u>	ast Effect	s of Bomb	Explosives,	PA Tech	Div Lectur	e, 9 April
(f) East Cavity Effec (g) Also	ern Labora t with Exp see the i	atory, du Polosive Com Collowing P:	ont, <u>Inves</u> position, i	tigation c NDRC Contr rsenal Tec	f Cavity Ef act W672-OR hnical Repo	fect, Sec D-5723. rts on To	III, Vari rpex:	ation of
<u>o</u>	<u>1</u>	2	<u>3</u>	5	<u>6</u>	<u>7</u>	<u>8</u>	
1530	1651	1292	2353	1585 1635 1885	1796	1797	1838	
				2355				

Composition:	Molecular Weight: $(C_6H_6N_6O_6)$	258
C 27.9 NH_2 H 2.3 O_0N NH_2 NO	Oxygen Balance: CO ₂ % CO %	-56 -19
	Density: gm/cc Crystal	1.93
0 37.2 NO ₂	Melting Point: °C 330 (b, e)	360 (a)
C/H Ratio 0.302	Freezing Point: °C	101
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	uille (1)
Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 11 Sample Wt, mg 7	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	E Webr
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C	
Rifle Bullet Impact Test: Trials % Explosions Partials		
Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm	42.9
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	0.30
20	Ballistic Mortar, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Trauzi Test, % TNT: Plate Dent Test: Method	
100°C Heat Test: % Loss, 1st 48 Hrs 0.00 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None	Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:		None
Hygroscopicity: %		Pressed 0.5
Volatility:	Density, gm/cc Rate, meters/second	1.80 7500

Fragmentation Test:	Shaped Charge Effectiveness, TN	T = 100:
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb	Glass Cones S Hole Volume Hole Depth	Steel Cones
Total No. of Fragments: For TNT	Color:	Yellow
For Subject HE	Principal Uses:	
3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib	 Live restrict for each in the large of the large state of	
Total No. of Fragments: For TNT	Method of Loading:	Pressed
For Subject FIE	Loading Density: gm/cc At 50,000 psi	1.80
At 9 ft At 25½ ft	Storage:	
Density, gm/cc	Method	Dry
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy	Hazard Class (Quantity-Distan Compatibility Group Exudation	ce)
Air Confined:	Detonation Velocity:	(a, b. c)
Impulse	Density, gm/cc	Meters/sec
Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure	1.290 1.345 1.675 1.675 1.882 1.835 <u>Heat of:</u>	5380 5628 6550 6575 7035 7220
Impulse Energy	Explosion, cal/gm	2831
	.01. epite 11	tion (exercise

Preparation:

(a)

Absolute alcohol (200 milliliters) was saturated with ammonia and then 12.5 gm (0.028 mol) of 1,3,5-tribromo-2,4,6-trinitrobenzene, prepared according to Hill (NAVORD Report No. 3709, 2 February 1953), was added. The flask was stoppered and allowed to stand at room temperature for a day. Additional ammonia was bubbled into the mixture, which was then heated under reflux for thirty minutes, filtered hot, and the insoluble product collected on a Buchner funnel. The product was washed with water, alcohol, and dried. The 4.7 gm of material recovered was recrystallized from nitrobenzene.

A disadvantage of the above method was that it could not be used for the preparation of large quantities of TATNB. Since it did not seem feasible to develop a new method of preparation, an investigation was made of the reported amination reactions (see <u>Origin</u> below). An attempt was made (Ref f) to find a modification which would produce high yields of a pure product. The process which evolved from this study may be summarized as follows (Ref f): 1,3,5trichlorobenzene was nitrated "in one step" to 1,3,5-trichloro-2,4,6-trinitrobenzene in 85% yield. The crude nitration product was aminated in benzene with ammonia gas to TATNB, in yields of at least 95%.

Origin:

TATNE was prepared for the first time in 1888 by C. L. Jackson and J. F. Wing, who found the compound insoluble in alcohol, ether, chloroform, benzene, and glacial acetic acid; and soluble in nitrobenzene and aniline (Amer Chem Journal 10, 282 (1888)). B. Flürscheim and E. L. Holmes prepared TATNE from benzene free pentanitroaniline by gradually adding it to 10% aqueous ammonia (J Chem Soc, Pt 2, 3045 (1928)). After boiling, an orange-yellow powder melting above 300°C was obtained. This product corresponded to that described by Jackson and Wing. These authors, as well as Palmer (Amer Chem Journal 14, 378 (1892)), attempted to reduce TATNE to hexa-aminobenzene. Either decomposition occurred or a hydrochloride of penta-aminobenzene was formed. Flurscheim and Holmes succeeded in reducing TATNE with phenylhydrazine by heating them together up to 200°C (J Chem Soc, Pt 1,334 (1929)) (Beil 13, 301 and EII, 147).

References:77

(a) F. Taylor, Jr., Synthesis of New High Explosives II, Derivatives of 1,3,5-Tribromo-2,4,6-Trinitrobenzene, NAVORD Report No. 4405, 1 November 1956.

(b) L. D. Hampton, <u>Small Scale Detonation Velocity Measurements from May 1951 to May 1954</u>, NAVORD Report No. 3731, June 1954.

(c) E. M. Fisher and E. A. Christian, <u>Explosion Effects Data Sheets</u>, NAVORD Report No. 2986, 14 June 1955.

⁷⁷See footnote 1, page 10.

Triethylene Glycol Dinitrate (TEGN) Liquid

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Composition:	Molecular Weight: $(C_6H_{12}N_2O_8)$	240
% / C 20.0 H C / C ⁿ 2 ^{UNO} 2	Oxygen Balance:	
	CO ₂ % CO %	-89 -27
H 5.4 H ₂ C	Density: gm/cc 20°C	1.33
N II. (H ₂ C	Melting Point: °C	1.32
0 53.0 H_2 CH ONO	Freezing Point: °C	
	Boiling Point: °C	
Impact Sensitivity, 2 kg with Bureau of Mines Apparatus, cm100+Sample Wt 20 mg Picatinny Arsenal Apparatus, in.43Sample Wt, mg43	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀	1.4540
Friction Pendulum Test:	Vacuum Stability Test:	ter sa
Steel ShoeUnaffectedFiber ShoeUnaffected	cc/40 Hrs, at 90°C	0.45
Rifle Bullet Impact Test: Trials %	120°C 8 hours 135°C	0.8
Explosions Partials	150°C	tooline antions
Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm	14.7
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 223	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide	
15		And International
20	Ballistic Mortar, % INT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method	ning state
100°C Heat Test: % Loss, 1st 48 Hrs 1.8 % Loss, 2nd 48 Hrs 1.6	Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:		Shelby steel
Hygroscopicity: %		Liquid 1.25
Volatility: 60°C, mg/cm ² /hr 40	Density, gm/cc Rate, meters/second	l.33 Fails

Fragmentation Test:	Shaped Charge Effectiveness, TNT =	100:
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Hole Volume Hole Depth	Cones
Total No. of Fragments: For TNT	Color:	110 B
For Subject HE	S galerouri	handle angeligen filmen der son
3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib	Principal Uses: Ingredient of roo base propellants	ket and double
Total No. of Fragments:		
For TNT	Method of Loading:	
	Loading Density; gm/cc	mail it 4
Fragment Velocity: ft/sec		regeri isilaR alfik
At 25½ ft	Storage:	
Density, gm/cc	Method	Liquid
Blast (Relative to TNT):	Hazard Class (Quantity-Distance)	
Air: Peak Pressure	Compatibility Group	
Impulse	Exudation	
Energy		
Air, Confined: Impulse	<u>gm/100 gm, at:</u> 25°C 60°C	0.55 0.68
Under Water: Peak Pressure	Solubility, gm/100 gm, at 25°C, in:	
Impulse	Ether	00
Energy	Alcohol 2:1 Ether:Alcohol	80
Underground: Peak Pressure	Acetone Viscosity, centipoises:	
Impulse	Temp, 20°C	13.2
Energy	Hydrolysis, % Acid:	
leat of:	10 days at 22°C 5 days at 60°C	0.032
Combustion, cal/gm Explosion, cal/gm	428 Vapor Pressure: 357 OC	mm Mercury
Gas vorume, CC/gm	25	<0.001

Origin:

Lourenco prepared triethylene glycol in 1863 by heating glycol with ethylene bromide in a sealed tube at 115°-120°C (Ann (3) 67, 275). Later in the same year Wurtz prepared triethylene glycol by heating ethylene oxide with glycol at 100°C. By action of nitric acid triethylene glycol was oxidized to (H₂OOC·CH₂·O-CH₂)₂ (Ann (3) <u>69</u>, 331, 351).

The Germans and Italians were the first to prepare and use TEGN during World War II as an ingredient of rocket and propellant powders. The commercial production of TEGN in quantity is still difficult and its use as a plasticizer for nitrocellulose is being replaced by other liquid nitrates.

Preparation:

Triethylene glycol is purified by fractional distillation under vacuum in an 18-inch Vigeaux fractioning column. The assembly as a whole is equivalent to 4.5 theoretical plates. The distillation is conducted using a 5 to 1 reflux ratio, at a pot temperature of approximately 180°C, and a take-off temperature of approximately 120°C.

The purified triethylene glycol (TEG) is nitrated by carefully stirring it into 2.5 parts of 65/30/5 nitric acid/sulphuric acid/water maintained at $0 \pm 5^{\circ}$ C. The rate of cooling is sufficient that 300 gm of TEG can be added within 40 minutes. The mixture is stirred and held at $0 \pm 5^{\circ}$ C, for 30 additional minutes. It is then drowned by pouring onto a large quantity of ice and extracted three times with ether. The combined extract is water-washed to a pH of about 4, shaken with an excess of sodium bicarbonate solution, and further washed with 1% sodium bicarbonate solution until the washings are colorless. The ethereal solution is water-washed until it has the same pH value as distilled water. It is carefully separated from excess water, treated with chemically pure calcium chloride to remove dissolved water, and filtered. The ether is removed by bubbling with dry air until a minimal rate of loss in weight is attained. The yield is 1.34 gm per gm TEG (84% of theoretical) and the nitrogen content of different batches range from 11.60 to 11.69% by the nitrometer method (calculated 11.67%).

(a) See the f	ollowing Picat	inny Arsenal 7	echnical R	eports on T	EGN:
<u>3</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	
1953 2193	1745	1786 2056	1767 1817	1638	
					and successive and successive states
					20 og distansstanget
78See footnot	e 1, page 10.				

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Trimonite

Composition:	Molecular Weight:	217		
Picric Acid 88 - 90	Oxygen Balance:	Courternal Martine Statements		
	CO %	-62 -14		
Mononitronaphtnalene 12 - 10	Density: am/cc Cast	1.60		
		1.00		
	Melting Point: °C	90		
C/H Ratio	Freezing Point: °C			
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 60	Boiling Point: °C Explodes	300		
Sample Wt 20 mg Picatinny Arsenal Apparatus in 10	Refractive Index, n ^D ₂₀			
Sample Wt, mg	n ^D ₂₅			
Friction Pendulum Test:	Vacuum Stability Test:	15.0 <u>0</u> 600		
Steel Shoe	cc/40 Hrs, at			
Fiber Shoe	90°C			
Rifle Bullet Impact Test: Trials				
%	120°C	0.9		
Explosions 0	135 C			
Partials 0		and the first		
Burned 0 Unaffected 100	200 Gram Bomb Sand Test: Sand, gm	44.2		
Explosion Temperature: °C Seconds, 0.1 (no cap used)	Sensitivity to Initiation: Minimum Detonating Charge, gm	ing data inf		
STATE AND	Mercury Fulminate			
5 Decomposes 315	Lead Azide	0.20		
15	Tetryl	0.04		
20	Ballistic Mortar, % TNT:			
	Trauzi Test, % TNT:			
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method			
100°C Heat Test	- Condition			
% Loss 1st 48 Hrs	Confined			
% Loss, 2nd 48 Hrs	Density, gm/cc			
Explosion in 100 Hrs	Brisance, % TNT			
	— Detonation Rate:			
Flammability Index:	Confinement	None		
Hyprocessisity, %	- Condition	Cast		
nygroscopicity: 70	Charge Diameter, in.	1.0		
Volatility:	Density, gm/cc 1.60			
	Rate, meters/second	7020		

Fragmentation Test:	Shaped Charge Effectiveness, $TNT = 100$:		
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones Steel Cones		
Density, gm/cc	Hole Volume		
Charge Wt, Ib	Hole Depth		
Total No. of Fragments:	Color:		
For TNT	the first second of the second second second		
For Subject HE	Principal Uses: TNT substitute in ;	projectiles	
3 inch HE, M42A1 Projectile, Lot KC-5:	and bombs		
Density, gm/cc			
Charge Wt, Ib	A long of the state state states when a state of the		
Total No. of Fragments:	Method of Loading:	Cast	
For TNT			
For Subject HE	Loading Density: gm/cc	1.60	
Fragment Velocity: ft/sec			
At 9 ft	Storeggy		
	Storage:		
Density, gm/cc	Method	Dry	
Blast (Relative to TNT):	— Hazard Class (Quantity-Distance)	Class 9	
Air: Peak Pressure	Compatibility Group	Group I	
Impulse	Exudation Exud	des at 50°C	
Energy			
Air, Confined:	Preparation:		
Impulse	Pieric seid and alpha-mononit	ropentthelene	
Under Water: Peak Pressure	are melted together in an alumin jacketed melt kettle equipped wi	um or tin steam th a stirrer.	
Impulse	perature for its melt loading (1	20°C), the	
Energy	mixture forms a eutectic melting must be taken to prevent the for	at 49°C. Care mation of dan-	
Underground: Peak Pressure	gerous metallic picrates. Trimor interest as an emergency substitu	nite is of ute for TNT.	
Impulse			
Energy			

Trimonite

Origin:

Trimonite, a castable mixture of picric acid/mononitronaphthalene was developed by the British during World War II as an improvement over tridite which is a mixture of 80/20 picric acid/dinitrophenol. Both mixtures are suitable for melt-loading below 100°C and therefore represent an improvement over melt-loading picric acid alone (melting point 122°C). However, tridite is slightly inferior to picric acid as an explosive and dinitrophenol is objectionable because of its toxicity. Trimonite is also slightly inferior to picric acid and TNT as an explosive. Because of the low eutectic temperature of the picric acid-mononitronaphthalene mixture (49°C), Tridite exudes when stored at elevated temperatures. It does not possess the disadvantages of picric acid (corrosive action on metals, ease of decomposition, etc.) and is a comparatively inexpensive substitute for TNT.

References: 79

(a) See t	he followi	ng Picatinny	Arsenal Techr	nical Rep	ports on Tri	monite: di avv spond
	2	5	<u>6</u>	8		
	1352	1325	926	1098		
	1372		976	1838		
Structure A						
⁷⁹ See for	otnote 1.	page 10.				

2,2,2-Trinitroethyl-4,4,4-Trinitrobutyrate (INETB)

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Composition:	Molecular Weight: $(C_6H_6N_6O_{14})$	386
% C 18.6	Oxygen Balance: CO ₂ % CO %	-4.2 20.8
N 21.8	Density: gm/cc Form I	1.78
C = 0	Melting Point: °C	93
C/H Ratio 0.202 CH ₂ CH ₂ C(NO ₂) ₃	Freezing Point: °C	n ten dan di se
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	a dental dent
Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg 50% point, cm (a) 20	Refractive Index, n20 Form I (e) Crystal Axis α β Υ) 1.518 1.527 1.546
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 48 hrs	0.60
Rifle Bullet Impact Test: Trials % Explosions Partials	120°C 135°C 150°C	ante la getarend vez erro
Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm	enal timati
Explosion Temperature: ^o C Seconds, 0.1 (no cap used) 1 5 50% point (Alhot bar) (a) 225 10	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	Contractor Carpor Mar Values, N
15	Ballistic Mortar, % TNT: (b)	136
	Trauzi Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs 100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	BC second con B (Investor) Denety (Con Bunderstation M
Explosion in 100 Hrs Flammability Index:	Detonation Rate: Confinement	riantal iotev 1
Hygroscopicity: % 30°C, 90% RH 0.00 75°C, 5 months Nil (a)	Condition Charge Diameter, in. Density, gm/cc 1.60 1.76	
Volatility:	Rate, meters/second 7760	8290

2,2,2-Trinitroethyl-4,4,4-Trinitrobutyrate (TNETB)

Booster Sensitivity Test: Condition	etripleWeeksistel	Decomposition Equation:	1 1 x 10 ²¹
Tetryl, am		(Z/sec)	4.4 X IO
Wax, in. for 50% Detonation		Heat, kilocalorie/mole	43.4
Wax, am		Temperature Range, °C	
Density, gm/cc		Phase	Liquid
Heat of: Combustion, cal/gm	1685	Armor Plate Impact Test:	Si manisati
Explosion, cal/gm		40 mm Morter Prejectile	
Gas Volume, cc/gm		50% Inert, Velocity, ft/sec	
Formation, cal/gm	307	Aluminum Fineness	
Fusion,col/gm Sublimation, cal/gm (est)	804	500-lb General Purpose Bombs:	
Specific Heat: cal/gm/°C			
(410)		Plate Thickness, inches	
		11/4	
Burning Rate:	1001	1-%4	
cm/sec		Barris Dava Tasta	1087-03
Thermal Conductivity: cal/sec/cm/°C	n i dan sette anni san status se Martin (San Sa) 	T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:	
Coofficient of Expension	THE REPORT OF A	Max Safe Drop, ft	
Linear, %/°C		500-lb General Purpose Bomb vs Concrete:	
Volume, %/°C		Height ft	
		Triols	
Hardness, Mohs' Scale:		Unoffected	
	T IN THE PARTY	Low Order	
Young's Modulus:		High Order	
E', dynes/cm²			
E, ID/Inch*		1000-lb General Purpose Bomb vs	Concrete:
Density, gm/cc		Height ft	
Compressive Strength: Ib/inch ²	Sumily, process		
		Unaffected	
Vanas Prossure:	(0)	Low Order	
$^{\circ}$ C mm Mercury 65 3.3 x 10 $\frac{-5}{4}$		High Order	
4.2×10^{-4}			n in der zeifenden Bel
$\begin{array}{cccc} 100 & 2.3 \times 10^{-3} \\ 120 & 1.4 \times 10^{-2} \end{array}$			

2,2,2-Trinitroethyl-4,4,4-Trinitrobutyrate (TNETB)

AMCP 706-177

Fragmentation Test:	Shaped Charge Effectiveness, $TNT = 100$:	
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Cones Hole Volume Hole Depth	
Total No. of Fragments: For TNT	Color: Colorless	
For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib	Principal Uses:	
Total No. of Fragments: For TNT	Method of Loading:	
For Subject HE Fragment Velocity: ft/sec	Loading Density: gm/cc Form I 1.783 Form II 1.677 Liquid, 99 ^o C. 1.551	
At 9 ft At 251/2 ft	Storage:	
Density, gm/cc	Method Wet	
Blost (Relative to H-6;: Sphere Cylinder (h) Air: 1-1b Charge: EW* EV* EW* EV* Peak Pressure 0.91 0.84 0.81 0.75 Impulse 0.73 0.67 0.74 0.69 Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy EW, equivalent weight of H-6 for a unit weight of test mixture for equal performance at the same test distance; EV, equivalent volume of H-6 for a unit volume of test mixture for equal performance at the same test distance.	Hazard Class (Quantity-Distance)Compatibility GroupExudationBruceton Safety Test Results:(g)Mean and standard deviation of lengths of0.300 diameter cylinder across which initia- tion is possible for 50% certainty:TNT 0.391 ± 0.040 RDX Comp BRDX Comp B 0.381 ± 0.042 TNETBTNETB 0.920 ± 0.059 Absolute Viscosity, poises:(e)Temp, 98.9° c 0.173 106.5° c0.138	
(a)

Solubility (Room Temperature):

Solvent	Solubility
Water	Insoluble
n-Hexane	Insoluble
Carbon tetrachloride	Insoluble
Ethanol	5 gm/100 gm solvent
Chloroform	5 gm/100 gm solvent
Benzene	10 gm/100 gm solvent
Nitromethane	Very soluble
Glacial acetic acid	Very soluble
Ethyl acetate	Very soluble

TNETB Forms Eutectics With the Following Compounds: (a)

-		and the second statement of the second statement of the second statement of the second statement of the second	
	INT	57	
	BUNES (his(trinitroethy]) succinate)	80+	
	DINED (DIB(OT INT OF DE ONIVE) BUCCTHAUC)	60.	- 1
	BINEN (bis(trinitroethyl) nitramine)	68.5	1
	TNB (trinitrobenzene)	65	ţ
	Compound A (CI, H <n, by<="" formed="" o,="" td=""><td>ni -</td><td></td></n,>	ni -	
	condensation of 1,1-dinitroethane)	77	Duc-
	Trinitroethyl trinitrobenzoate (27%)	80.5 (f)	E.

Crystallographic Data:

(a)

Three polymorphic crystalline forms have been observed. Low temperature Form I goes through a solid-solid transition at 89° C giving Form II. Form II has a melting point of 92.5° to 93° C. On cooling, Form II does not transform reversibly to Form I when 89° C is reached. However, Form II will transform to Form I at room temperature, usually taking a few hours to do so. Form III was observed, which appeared to be stable over a very narrow temperature range on the order of 0.2° to 0.3° C near 92.5° C.

Preparation:

(d)

(NO2) 3 CCH CH 2 COCI (NO2) 3 CH2 OH + H2SOL trinitrobutyryl chloride trinitroethanol sulfuric acid (NO2) 3 CCH2 CH2 COOCH2 C(NO2) 3 HCl

2,2,2-trinitroethyl-4,4,4-trinitro-hydrochloric butyrate acid

Laboratory experiments indicate that the present slow step involving overnight treatment of 4,4,4-trinitrobutyryl chloride with 2,2,2-trinitroethanol and aluminum chloride can be replaced by a fast and simple esterification in sulfuric acid. Using 100% sulfuric acid or fortified H_2SO_4 , the ester can be prepared in yields of 95% to 98% in 24 hours at 25°C, in 5 hours at 50°C, or in 3 hours at 65°C. Above 65°C the reaction time is less, but the yield falls off and a less pure product is obtained. The crude white crystalline product on recrystallization from dilute methanol gives a material melting at 92° to 93°C.

Origin:

(e)

TNETB belongs to a new class of explosives characterized by trinitromethyl groups, -C(NO₂)₃. The chemistry of this class of compounds was studied in Germany by Drs. Schenck and Schimmelschmidt, who discovered in 1942-1943 that trinitromethane or nitroform, $HC(NO_2)_3$, was the source of new explosive derivatives. Dr. Schenck prepared the stable solid alcohol, 2,2,2-trinitroethanol, from nitroform and formaldehyde. Dr. Schimmelschmidt reacted nitroform with unsaturated organic compounds, such as acrylic acid, and predicted in 1943 that the ester of 4,4,4-trinitrobutyric acid with trinitroethanol would be an interesting explosive.

In 1947 the U.S. Navy began a program to explore these compounds. The initial task of investigating the chemistry of trinitroethanol was undertaken by the Hercules Powder Company (Navy Contract NOrd-9925). The U.S. Rubber Company studied the chemistry of nitroform (Navy Contract NOrd-10,129). After preparation of the first laboratory samples of TNETB, considerable interest was aroused. In early 1950 the Naugatuck Chemical Division of U.S. Rubber Company was assigned to prepare 100 pounds of TNETB. The Bureau of Ordnance in July 1953 raised the production to 800 pounds with the assistance of the Hercules Powder Company in augmenting the production at Naugatuck (Navy Contract NOrd-11,280). TNETB is a high oxygen content explosive.

References: 80

(a) J. M. Rosen, Properties of Trinitroethyl Trinitrobutyrate TNETB, NAVORD Report No. 1758, 17 December 1950.

(b) Bureau of Mines Report No. 3107, Part IX, <u>Ballistic Mortar Tests on Trinitroethyl</u> Trinitrobutyrate, 5 April 1950.

(c) L. D. Hampton and G. Svadeba, Evaluation of 2,2,2-Trinitroethyl-4,4,4-Trinitrobutyrate as a Constituent of Castable Explosives, NAVORD Report No. 2614, 30 September 1952.

(d) U.S. Rubber Company Quarterly Progress Report No. 23, Synthesis of New Propellants and Explosives, Navy Contracts NOrd-10-129 and -12,663, 19 August 1953.

(e) M. E. Hill, O. H. Johnson, J. M. Rosen, D. V. Sickman and F. Taylor, Jr., Preparation and Properties of INETB, a New Castable High Explosive, NAVORD Report No. 3885, 27 January 1955.

(f) M. E. Hill, Synthesis of New High Explosives, NAVORD Report No. 2965, 1 April 1953.

(g) Jacob Savitt, A Sensitivity Test for Castable Liquid Explosives, Including Results for Some New Materials, NAVORD Report No. 2997, 22 October 1953.

(h) R. W. Gipson, Sensitivity of Explosives, IX: Selected Physico-Chemical Data of Ten Pure High Explosives, NAVORD Report No. 6130, 18 June 1958. Trinitro Triazidobenzene

Composition:	Molecular Weight: $(C_6O_6N_{12})$ 336			
C 21.4 N_3 V_2 N_3	Oxygen Balance: CO ₂ % CO %	-29 0.0		
	Density: gm/cc Crystal	1.81		
0 28.6 2 2	Melting Point: °C Decomposes	131		
C/H Ratio	Freezing Point: °C	o várt at		
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus cm (a) \$25	Boiling Point: °C	Carlos Carlos		
Sample Wt 20 mg	Refractive Index, n ^D ₂₀	western all to		
Sample Wt, mg	n ₂₅			
Existing Dandylung Test				
Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C			
Rifle Bullet Impact Test: Trials %	- 100°C 120°C 135°C			
Partials	150°C			
Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm	d hellowed in 1948		
Explosion Temperature: °C (a) Seconds, 0.1 (no cap used) 1 1 5 150 10 15 15 15 15 15	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	n hall strint from 19 - 20 - (19) 19 - 20 - (19) 29 - 20 - (19)		
20	Ballistic Mortar, % TNT:			
	•Trauzl Test, % PETN:	90		
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method	ही बहुनी, लहुह		
100°C Heat Test:	Condition			
% Loss, 1st 48 Hrs	Confined			
% Loss, 2nd 48 Hrs	Density, gm/cc			
Explosion in 100 Hrs				
Flammability Index:	- Detonation Rate: Confinement			
Hygroscopicity: % 30 [°] C, 90% RH 0.00	Condition Charge Diameter, in.			
Volatility:	Density, gm/cc Rate, meters/second			

Trinitro Triazidobenzene

ragmentation Test:	Shaped Charge Effectiveness, T	NT = 100:
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Hole Volume Hole Depth	Steel Cones
Total No. of Fragments: For TNT	Color: Gr	eenish-yellow
For Subject HE	Principal Uses: (c) Ingre	dient of primer mix
3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib		
Total No. of Fragments: For TNT	Method of Loading: Dead presses at about	Pressed 5 42,000 psi
	Loading Density: gm/cc At 42,000 psi	1.75
ragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method	
Blast (Relative to TNT):	Hazard Class (Quantity-Dis	tance)
Air: Peak Pressure Impulse	Compatibility Group Exudation	None
Energy Air, Confined:	Qualitative Solubilitie at Room Temperature:	<u>s</u>
Impulse	Solvent	Solubility
Under Water: Peak Pressure Impulse	Acetone Chloroform Alcohol Water	Readily soluble Moderately soluble Sparingly soluble Insoluble
Energy	Compatibility with Meta]s:
Underground: Peak Pressure	Wet: Does not attac or brass.	k iron, s teel, copper
Impulse	Heat of:	
Energy	Combustion, cal/gm	(a) 2554
	Burning Rate:	(b)

Trinitro Triazidobenzene



Aniline is chlorinated to form trichloroaniline. The amino group is eliminated by the diazo reaction. The resulting sym-trichlorobenzene is nitrated. This nitration is carried out by dissolving the material in warm 32% oleum, adding strong nitric acid, and heating to $140^{\circ}-150^{\circ}C$ until no trinitro trichlorobenzene (melting point $187^{\circ}C$) precipitates (Ref f). The chlorine groups are then replaced by azo groups. This is accomplished by adding an acetone solution of the trinitro trichlorobenzene, or better, and powdered substance alone, to an actively stirred solution of sodium azide in alcohol. The precipitated trinitro triazidobenzene is collected on a filter, washed with alcohol, water and dried. It may be purified by dissolving in chloroform, allowing the solution to cool, and collecting the greenish yellow crystals (melting point $131^{\circ}C$ with decomposition).

Origin:

This initiating explosive was first prepared in 1923 by Turek who also perfected its manu-facture.

References:81

(a) S. Helf, <u>Tests of Explosive Compounds Submitted by Arthur D. Little, Inc.</u>, PATR 1750, 24 October 1949.

(b) A. F. Belyaeva and A. E. Belyaeva CR a.s. USSR <u>52</u>, 503-505 (1946) Chemical Abstracts <u>41</u>, 4310.

A. E. Belyaeva and A. F. Belyaeva, Doklady Akad Nauk. USSR 56, 491-494 (1947).

(c) French Patent 893,941, 14 November 1944 (Chemical Abstracts 47, 8374).

(d) A. D. Yoffe, "Thermal Decomposition and Explosion of Azides," Proc. Roy Soc A208, 188-199 (1951).

(e) T. L. Davis, <u>The Chemistry of Powder and Explosives</u>, John Wiley and Sons, Inc., New York (1943), p. 436.

(f) O. Turek, Chim et Ind 26, 781 (1931); German Patent 498,050; British Patent 298,981.

⁸¹See footnote 1, page 10.

Tripentaerythritol Octanitrate (TPEON)

AMCP 706-177

Composition:	Molecular Weight: $(C_{15}H_{24}N_8O_{26})$	732		
% C 24.6 H 3.3 N 15.3	Oxygen Balance: CO ₂ % CO %	-35 -2.2		
0 56.8 CH_ONO_ CH_ONO_ CH_ONO_	Density: gm/cc Crystal	1.58		
o2NocH2ccH2ocH2ccH2ocH2ccH2oNo2	Melting Point: °C 82 to 84			
C/H Ratio 0.175	Freezing Point: °C	Heat also Comparish		
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	ing notice with		
Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 9 Sample Wt, mg 24	Refractive Index, n ^D ₂₀ n ^D ₂₅ n ^D ₃₀			
Friction Pendulum Test:	Vacuum Stability Test:	sinte particular		
Steel Shoe Unaffected	cc/40 Hrs, at 90°C			
Fiber Shoe Onarrected		2.45		
Rifle Bullet Impact Test: Trials	120°C Specially purified	1.94		
%	135°C			
Explosions	150°C			
Partials	200 Gram Bomb Sand Test:	and the state		
Burned Unaffected	Sand, gm	58.9		
Explosion Temperature: °C Seconds, 0.1 (no cap used)	Sensitivity to Initiation: Minimum Detonating Charge, gm			
1	Mercury Fulminate	na te ten <u>ovan</u> eta		
5 225	Lead Azide	0.30		
10	Tetryl	Network, State		
15 20	Ballistic Mortar, % TNT:			
Unot rupted	Trauzi Test, % TNT:			
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test:			
	Condition			
100°C Heat Test:	Confined			
% Loss, 1st 48 Hrs 1.15	Density, gm/cc			
% Loss, 2nd 48 Hrs U.15	Brisance, % TNT			
Explosion in 100 Hrs None	Detonation Rate:			
Flammability Index:	Confinement	None Pressed		
Hygroscopicity: %	Charge Diameter, in.	0.5		
Volatility:	Density, gm/cc Rate, meters/second	7650		

Tripentaerythritol Octanitrate (TPEON)

Booster Sensitivity Test: Condition		Decomposition Equation:	
Tetryl, am		(Z/sec)	
Wax, in. for 50% Detonation		Heat, kilocalorie/mole	23.1
Wax, am		(ΔH, kcal/mol)	015 4 050
Density, am/cc		Phose	215 to 250
	Author False	- Phase	Liquid
Heat of: Combustion, cal/gm	2632	Armor Plate Impact Test:	Street Barrier
Explosion, cal/am	1085	and the second	
Gas Volume, cc/am	762	60 mm Mortar Projectile:	
Formation, cal/am	ment optimation	50% Thert, velocity, tt/sec	
Fusion, cal/am		Aluminum Fineness	
		500-lb General Purpose Bombs:	
Specific Heat: cal/gm/°C			
Specific Impulse:		Plate Thickness, inches	
lb-sec/lb (calculated)	240	landa a pilo na naj sel	
	2-0	-main and the line and the second sec	
		174	
	1.11	13/	
Burning Rate:	1.054	1.74	
cm/sec		Bomh Dron Toot	turne) wy A
Thermal Conductivity	WALL THREE	Domb Drop Test:	
cal/sec/cm/°C		T7, 2000-Ib Semi-Armor-Piercing	Bomb vs Concrete:
Coefficient of Expansion:	i i cana a c	Max Safe Drop, ft	
Linear, %/°C	s of a line l	500-Ib General Purpose Bomb v	Concrete:
Volume, %/°C	1000		
		Height, ft	
Hardness, Mohs' Scale:		Trials	
141 	C. Cart (aged) 1.	Unattected	
Young's Modulus:	1 Contraction 11	Low Order	
E', dynes/cm²	- and the		
E, Ib/inch ²	s with the later of the	1000-lb General Purpose Bomb ve	Concrete:
Density, gm/cc	Seate AD		- The second sec
Companyation for an in the second		Height, ft	
compressive Strength: Ib/inch ²	Т.Р. ковыть	Trials	
		Unaffected	
Vapor Pressure:	Carlineta	Low Order	
"C mm Mercury	nortificero D	High Order	
	Cinter 1 Internet		1
	and adjoint	and the second	and the second

Tripentaerythritol Octanitrate (TPEON)

AMCP 706-177

ragmentation Test:	Shaped Charge Effectiveness, $TNT = 100$:		
90 mm HF M71 Projectile, Lat WC-91:	Glass Cones Steel Cones		
Density am/cc	Hole Volume		
Charge W+ Ib	Hole Depth		
Charge Wit, in			
Total No. of Fragments:	Color: White		
For TNT			
For Subject HE	Principal Uses: High explosive and as possib		
3 inch HE, M42A1 Projectile, Lot KC-5:	prasticizer for in deterrite		
Density, gm/cc			
Charge Wt, Ib			
Total No. of Fragments:	Method of Loading: Cast or presse		
For TNT			
For Subject HE	Loading Density: am/cc		
	Pressed at 60,000 psi 1.56		
Fragment Velocity: ft/sec			
At 9 ft At 251/2 ft	Storage:		
Density, gm/cc	Marked Drv		
	Method		
Blast (Relative to TNT):	Hazard Class (Quantity-Distance)		
	Compatibility Group		
Air:	Company		
Peak Pressure	Exudation None		
Impulse	Constant of the second second second second second second		
Energy	Hygrosconicity, Gain or Loss in Wt. %:		
Air, Confined:	nygroscopicity, dain of hour in we, pr		
Impulse	Time, Hrs % RH at 30°C		
the first of the second s	40 70 90		
Peak Pressure			
Impulse	$\begin{array}{cccccccccccccccccccccccccccccccccccc$		
Energy	144 -0.04 -0.03 -0.02		
	192 -0.04 -0.02		
Underground: Peak Pressure	216 -0.004 -0.01 +0.03		
Impulse	Solubility:		
Energy	Solvent Solubility		
	WaterInsolubleAlcoholSolubleChloroformSolubleAcetone, hotVery solubleBenzene, hotVery soluble		

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Tripentaerythritol Octanitrate (TPEON)

Compaction of whether might Exprost	ompacipitity	with other H	ign Explosives:	2
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100°C Vacuum Stability Test:

Herina	NTN	PETN	RDX	TPEON
ml gas/40 hrs, 5 gm sample	0.14	2.15	0.39	2.45
ml gas/40 hrs, 5 gm sample of 50/50, TPEON/HE	1.89	1.71	2.32	ាងកំពុងស្វែង

Dipentaerythritol Hexanitrate (DPEHN)-TPEON Fusions:

% TPEON	% DPEHN Sol	idification Time, Days	MP, °C	3 incident and a second
100	0		83	Cierge Wr, Is
95	5 april rod to	bastro M 3	68	Tene Has al Fre
90	10	3	69	THE THE
80	2011/1021	enibeo.i 5	73	
50	50	30	60 (Eutecti	c)
20	80	5	63	A STREET
10	90 ba	3	69	00 100 200 000
0	100	undH	73	ai evitetal? tud

Preparation:

(a) Compatibility Group

Twenty grams (0.054 mol) of nitration grade tripentaerythritol (TPE) (99%) minimum purity) were slowly added, with stirring, to 160 gm (2.55 mol) of 99% nitric acid at a temperature of -25° to 0°C. On equivalent weight basis, this quantity of 99% nitric acid corresponds to an excess of 6.3 times the TPE used. After addition of the TPE, the reaction mixture was stirred for about one hour at 0° to 5°C and poured into eight times its volume of cracked ice. The product, when allowed to stand overnight, was crushed under water; filtered with suction; and washed copiously with water. It was then treated twice with about 5 times its weight of a 1% ammonium carbonate solution, stirred for several hours, filtered and washed with water until the final washings were neutral to litmus. The final product was washed successively with 50 cc each of ethanol and ether. The material dried in air weighed 37.8 gm or 96% of theory based on TPE. It had a melting range of 71° to 74°C. Crystallization of the crude TPEON from chloroform was found to be the most suitable method of obtaining pure TPEON.

Origin:

U.i. dargenum

TPEON prepared by the reaction of tripentaerythritol and 99% nitric acid at 0° to 10° C was reported by Wyler in 1945 (J. A. Wyler to Trojan Powder Company: U.S. Patent 2,389, 228, 20 November 1945).

References: 82

(a) J. J. LaMonte, H. J. Jackson, S. Livingston, L. B. Silberman and M. M. Jones, <u>The</u> Preparation and Explosive Properties of Tripentaerythritol Octanitrate, PATR No. 2490, 1958.

(b) K. Namba, J. Yamashita and S. Tanaka, "Pentaerythritol Tetranitrate," J Ind Explosives Soc (Japan) <u>15</u>, 282-9 (1954); CA <u>49</u>, 11283 (1955).

(c) S. D. Brewer and H. Henkin, The Stability of PETN and Pentolite, OSRD Report No. 1414.

(d) E. Berlow, R. H. Barth and J. E. Snow, The Pentaerythritols, ACS Monograph No. 136, Reinhold Publishing Corporation, New York, 1958.

		75 C International Heat Tank % Law m 45 Km
		ityeresseptister in 20 ¹⁰ 0, 9
822	Clevelty, gm/cc	

³²See footnote 1, page 10.

Tritonal, 80/20

Composition:		Molecular Weight:		81
70 INT	80	Oxygen Balance: CO ₂ %	ut jamainat Liintusti. 3a	-77
Aluminum	20	CO %		- 38
		Density: gm/cc	Cast	1.72
		Melting Point: °C	10 T. M. 18	d = d = (u)
C/H Ratio		Freezing Point: °C	داغي آب ج	el 31 (b)
Impact Sensitivity, 2 Kg Wt:	85	Boiling Point: °C		
Sample Wt 20 mg	0)	Refractive Index, n ^D ₂₀		
Picatinny Arsenal Apparatus, in.	13	n P		
Sample Wt, mg	16	n ₃₀		
Friction Pendulum Test:		Vacuum Stability Test		
Steel Shoe Una	ffected	cc/40 Hrs of		
Fiber Shoe Una	ffected	90°C		
		100°C		0.1
Rifle Bullet Impact Test: Trials		120°C		0.2
5		135°C		
Explosions 60		150°C		0.8
Partials 0				
Burned		200 Gram Bomb Sand Test:		
Unaffected 40		Sand, gm		
Explosion Temperature: °C		Sensitivity to Initiation:		and the second
Seconds, 0.1 (no cap used) 610		Minimum Detonating Ch	arge, gm	
1 520		Mercury Fulminate		
5 Decomposes 410		Lead Azide		0.20
10 405		Tetryl		0.10
20	λ	Ballistic Mortar, % TNT:	(a)	124
75°0	an ann an	Trauzl Test, % TNT:	(b)	125
% Loss in 48 Hrs		Plate Dent Test:	(c)	
	and the state of the	Method		В
100°C Heat Test:		Condition		Cast
% Loss, 1st 48 Hrs		Confined		No
% Loss, 2nd 48 Hrs		Density, gm/cc		1.75
Explosion in 100 Hrs		Brisance, % TNT		93
Flammability Index:	100	Detonation Rate:	None	Mara
		Continement	None	None
Hygroscopicity: % 30°C. 90% RH	0.00	Condition	Cast	Pressed
		Charge Diameter, in.	1.0	1.0
Volatility:		Density, gm/cc	1.71	1.72
		Rate, meters/second	6475	6700

Cooster Sensitivity Test: (d) Condition	Cast	Decomposition Equation: Oxygen, atoms/sec (7/sec)		
Tetryl, gm Wax, in. for 50% Detonation	0.58	Heat, kilocalorie/mole (ΔH, kcal/mol)		
Wax, gm		Temperature Range, °C		
Density, gm/cc	1.75	Phase		
leat of: (c) Combustion, cal/gm	4480	Armor Plate Impact Test: (e)	eA.
Explosion, cal/gm Gas Volume, cc/am	1770	60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec	509	>1100
Formation, cal/gm		Aluminum Fineness	100	12
Fusion, cal/gm		500-1b General Purpose Bombs	and the second	
pecific Heat: cal/gm/°C (b)	0.23	Plate Thickness, inches	Trials	% Inert
	1.74	1	0	
Density, gm/cc	T•14	11/4	• 6	100
At 20°C	0.31	11/2	6	33
	(Approximate)	13/4	0	
cm/sec Thermal Conductivity: cal/sec/cm/°C (b) Density.gm/cc	11 x 10 ⁻⁴ 1.73	Bomb Drop Test: (e) T7, 2000-lb Semi-Armor-Pierc	ing Bomb vs	s Concrete:
Coefficient of Expansion: Linear, %/°C	mborat en 2	Max Safe Drop, ft 500-Ib General Purpose Bomb	vs Concret	e:
Volume, %/°C		Height, ft	Seal 4,000	Seal 5,000
		- Trials	32	14
Hardness, Mohs' Scale:		Unaffected	54	14
Y (a Madulus) (b)		Low Order	0	0
Fi dunos (cm²	6.67 x 10 ¹⁰	High Order	4	0
E, dynes/cm ⁻	0.97 x 10 ⁶	1000-lb General Purpose Rom	b vs Concret	te:
	1.72	Toot-In General Furbase Bonn		Seal
Density, gin/ cc		Height, ft		5,000
Compressive Strength: Ib/inch ² (b)	2340	Trials		24
Density, gm/cc	1.75	Unaffected		23
N		Low Order		0
°C mm Mercury		High Order		1

Tritonal, 80/20

Fragmentation Test:		Shaped Charge Effectiveness, TNT	= 100:
90 mm HE, M71 Projectile, Lot WC	C-91:	Glass Cones Ste	eel Cones
Density, gm/cc	1.71	Hole Volume	Tetryi and
Charge Wt, Ib	2.272	Hole Depth	
Total No. of Fragments:			Designed and
For TNT	703	Color:	Gray
For Subject HE	616	Principal Hanne (ID hawke	and a state
3 inch HE, M42A1 Projectile, Lot K	C-5:	Frincipal Uses: GP bombs	
Density, gm/cc	1.73	Company	
Charge Wt, Ib	0.914		
Total No. of Fragments:			Puples, col/ cm
For TNT	514	Method of Loading:	Cast
For Subject HE	485	Landian Dansitan any (ag	1 (5 1 70
ragment Velocity: ft/sec	UP.	Lodding Density: gm/cc	1.07-1.(2
At 9 ft At 251/2 ft	2460 2380	Storage:	They a
Density, gm/cc	1.72		
	and the second second	Method	Dry
last (Relative to TNT):	(f)	Hazard Class (Quantity-Distance)	Class 9
Air:		Compatibility Group	Group T
Peak Pressure	110	and the second sec	
Impulse	115	Exudation	
Energy	119		C / (s. lipliu));
Air, Confined:		Preparation:	
Impulse	130	Tritonal is prepared by add	ing TWT and
11 I W .		aluminum separately to a stea	m-jacketed mel
Peak Pressure	105	kettle equipped with a stirre	r. Heating of
Impulse	102	the kettle and mixing of the	ingredients ar
Energy	119	the viscosity of the mixture	is considered
Inch		poured into projectiles or bo	e tritonal is mbs the same a
Underground:	el poloinel	TNT.	and bane a
Peak Pressure	117	th Bolleght (F) 20hil	
Impulse	127	1	
Energy	T 30		
		Anna Maraare	

Origin:

The Addition of aluminum to increase the power of explosives was proposed by Escales in 1899 and patented by Roth in 1900 (German Patent 172,327). Some recent studies, directed towards establishment of the optimum amount of aluminum in the TNT/Aluminum system, have shown that (1) the blast effect increases to a maximum when the aluminum content is 30% (Ref g); the brisance, as measured by the Sand Test, passes through a maximum at about 17% aluminum (Ref h); in Fragmentation Tests, no maximum is observed, additions of aluminum causing a decrease in efficiency over the entire range from 0% to 70% aluminum (Ref i); and (4) the rate of detonation of cast charges is continuously decreased by additions of aluminum up to 40% (Ref j). For all practical purposes it is concluded that the addition of 18% to 20% aluminum to TNT improves its performance to a maximum. This conclusion is in agreement with that of British workers who measured performance of aluminized TNT-mixtures based on extensive Lead Block Test data (Ref k).

Tritonal, consisting of 80% TNT and 20% aluminum, was developed and standardized in the United States during World War II for use in bombs.

References:83

(a) L. C. Smith and E. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) L. C. Smith and S. R. Walton, <u>A Consideration of RDX/Wax Mixtures as a Substitute for</u> Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(e) Committee of Div 2 and 8, NDRC, Report on HBX and Tritonal, OSRD No. 5406, 31 July 1945.

(f) W. R. Tomlinson, Jr., <u>Blast Effects of Bomb Explosives</u>, PA Tech Div Lecture, 9 April 1948.

(g) W. B. Kennedy, R. F. Arentzen and C. W. Tait, Survey of the Performance of TNT/Al on the Basis of Air-Blast Pressure and Impulse, OSRD Report No. 4649, Division 2, Monthly Report No. AES-6, 25 January 1945.

(h) W. R. Tomlinson, Jr., Develop New High Explosive Filler for AP Shot, PATR No. 1290, First Progress Report, 19 May 1943.

(i) W. R. Tomlinson, Jr., <u>Develop New High Explosive Filler for AP Shot</u>, PATR No. 1380, Second Progress Report, 12 January 1944.

(j) L. S. Wise, Effect of Aluminum on the Rate of Detonation of TNT, PATR No. 1550, 26 July 1945.

(k) Armament Research Dept, The Effect of Aluminum on the Power of Explosives, British Report AC-6437, May 1944 (Explosives Report 577/44).

83See footnote 1, page 10.

Tritonal, 80/20

(1) Also see the following Picatinny Arsenal Technical Reports on Tritonal:

<u>o</u>	<u>3</u>	<u>4</u>	5	6	<u>7</u>	8
1530 1560 2010	1693 2353	1444	1635	1956	1737 2127	2138

tietteksente, om passengen mensk 200 mini 193 afgebolge, smak kaste operne med mode men søne tekse på en enge Gebore er som om over kom i 100 for anti- af passinge.

11-14-10-12-1-12-

, stalje jedno je se konstruktor po deleta po stalje od <u>jedna se se konstruktor. U sl</u>e jezdela u zasle od nastru Po konstruktor se nastruktor u stalje od nastruktorije.

(4) Construction of the construction of fourier interaction (4) and the construction of the construction (4).

 ~ 0.401 where $c_{\rm e} \sim 0.01$ and $c_{\rm e} \sim 0.001$ MeV ~ 0.001 MeV ~ 0.01 MeV ~ 0.01

(도) 이 가는 이 이 가지 않는 것이 가지 <u>이 바람이 가 한 가지만 다시 것 이다. 전철에 걸려 있는 아</u>들과 아들에 만들었다. 이는 것 같아요. 이 가지 않았다. A.U.

가지는 것이 가지 않는 것이 가지 않는 것이 가지 않는 것이 <u>가지 않는 것이 가지 않는 것이 같이 있다. 것이 있는 것이 있는 것이 있는 것이 있다. 이 것이 있</u>는 것이 있었다. 2013년 11년 - 11년 2017년 2

(4.) The second result of the basis of the second s second s second sec second sec

(iii) strategies of the second strategies of the second strategies and the second strategies (second strategies) with the second strategies) with the second strate

Veltex No. 448*

			-0
Composition:	designation of the	Molecular Weight:	281
% HMX	70.0	Oxygen Balance:	me bala
Nitrocellulose (13.15% N)	15.0	CO2 %	-26
Nitroglycerin	10.7	CO %	-0.5
2-Nitrodiphenylamine	1.3	Density: am/cc Pressed	1.72
Triacetin	3.0	Melting Point: °C	
	and the second of		the second
C/H Ratio		Freezing Point: °C	Combines -
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C	and the
Sample Wt 20 mg		Refractive Index, n ^D ₂₀	
Picatinny Arsenal Apparatus, in.		n ₂₅	
Sample Wt, mg		n ₃₀	
Friction Pendulum Test:	el midi	Vacuum Stability Test:	nistrational)
Steel Shoe Uns	affected	cc/40 Hrs, at	
Fiber Shoe Uns	affected	90°C	
		100°C	1.29
Rifle Bullet Impact Test: Trials		120°C 29 hours	11+
%		135°C	
Explosions		150°C	
Partials			
Burned		200 Gram Bomb Sand Test:	
Unaffected	a nume set	Sand, gm	66.4
Explosion Temperature: °C		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm	th mendline 2
damaged as Smill around line		Mercury Fulminate	
5		Lead Azide	0.30
10		Tetryl	
15		Ballistic Mortar, % TNT:	Saidinage Feat
20	and the second	Trauzi Test, % TNT:	
75°C International Heat Test:		Plate Dent Test:	na kana 19
% Loss in 48 Hrs		Method	
and the second		Condition	
90 °C Heat Test:	2 0	Confined	
% Loss, 1st 48 Hrs 0.	28	Density am/cc	
% Loss, 2nd 48 Hrs 1.	12	Brisance % TNT	and the second second
Explosion in 100 Hrs No	one		
Flammability Index:	sið ligili	Detonation Rate: Confinement Condition	
Hygroscopicity: %		Charge Diameter, in.	
Volatility:		Density, gm/cc Rate, meters/second (calculated)	8500

*See footnote on following page.

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Veltex No. 448*

Condition		Decomposition Equation:	
Tetryl, am		(Z/sec)	
Wax in for 50% Detonation		Heat, kilocalorie/mole	
Wax, m. for 50 % Detonation		(AH, kcal/mol)	
wax, gm		Temperature Range, °C	
Density, gm/cc		Phase	
Heat of:	Statutes Butters	Armor Plata Impact Test	
Combustion, cal/gm	2359	Annot Flate Impact Test:	
Explosion, cal/gm	1226	60 mm Mortar Projectile:	
Gas Volume, cc/gm		50% Inert, Velocity, ft/sec	
Formation, cal/gm		Aluminum Fineness	
Fusion, cal/gm		 A second sec second second sec	
		500-1b General Purpose Bombs:	
Compression at Rupture: %	8.26	Plate Thickness, inches	
		Prove and Develop 17	
Work to Produce Rupture:		Loss write early	
ft-lb/inch ³	9.62	11/4	
		11/2 mbasi i seter	
	and the second	13/4	
Burning Rate:			
cm/sec		Bomb Drop Test:	and the second se
Thermal Conductivity:	reg house	TT 2000-lb Semi-Armor Pioreine	Romb we Consider
		stry zeee is semi-Armor-Hereing	bomb vs Concrete:
Coefficient of Expansion:	internited instantiality.	Max Safe Drop, ft	
Linear, %/°C		EOO IL Consul Duran Bul	• • • • • • • • • • • • • • • • • • •
		SUC-ID General Purpose Bomb vs	Concrete:
Volume, %/°C		Height ft	
		Triols	
Hardness, Mohs' Scale:		lipoffected	
Young's Modulus:	And the second s	Low Order	
E', dynes/cm ²	0.24×10^{10}	High Order	
E, Ib/inch ²	0.35 x 10 ⁵		
Density, gm/cc	Candillan	1000-10 General Purpose Bomb vs	Concrete:
	Centined	Height, ft	
Compressive Strength: Ib/inch ²	2720	Triols	
Construction of the second s	That we wanted in the	Lineffected	
lanas Brannas			
°C mm Marcum	19-30-27 ADDISON-09-64	Low Urder	
	mangetting.)	High Order	
	Coldinates	and the design of the second se	
Name assigned by Dr. Mark I	M. Jones, formerly		a secondorand and
of the paper on on stilling (everopment by		

Veltex No. 448

AMCP 706-177

Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100:	
90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Cones Hole Volume Hole Depth	
Total No. of Fragments: For TNT	Color:	Orange
For Subject HE	Principal Uses: High mechanical streng machinable explosive	th
3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, Ib		ar athla
Total No. of Fragments: For TNT	Method of Loading:	Pressed
For Subject HE	Loading Density: gm/cc	1 70
Fragment Velocity: ft/sec At 9 ft At 25½ ft	At 6,700 psi Storage:	1.72
Density, gm/cc	Method	Dry
Blast (Relative to TNT):	Hazard Class (Quantity-Distance)	
Air: Peak Pressure	Compatibility Group	Mana
Impulse Energy	Exudation Machinability	Exceller
Air, Confined: Impulse		
Under Water: Peak Pressure		
Impulse Energy		
Underground: Peak Pressure		
Impulse		
Energy		

Veltex No. 448

Preparation:

The preparation of this class of explosive compositions is illustrated by the method used for Veltex No. 448: Place 675 cc of water in a slurry kettle equipped with an agitator. Add 5.85 gm of 2-nitrodiphenylamine and agitate for several minutes to obtain dispersion. Then add 93.7 gm of water-wet nitrocellulose (dry weight 67.5 gm) in small portions. Raise the temperature to 48° C and maintain this temperature, but continue the agitation. A mixture of 48.2 gm of nitroglycerin and 13.5 gm of triacetin is added over a 5-minute period, with the mixing continuing for an additional 10 minutes at 48° C. The HMX (350 gm) is added over a 5-minute period with agitation continued for 30 minutes at 48° C. The slurry is cooled to room temperature and filtered. The filter cake is dried to a moisture content between 8% and 12%. The incorporation of this mix is completed by rolling 50 gm portions at a temperature of approximately 90°C. The finished colloid is then preheated on a heat table at 66° C. Increments of 25 gm each are pressed at 6700 psi for four minutes at 71°C. A cylinder is then built up by pressing together four 25 gm increments for a dwell time of 15 minutes.

Origin:

Veltex is the name given to a series of closely related nitrocellulose compositions prepared in 1957 at Picatinny Arsenal by the solventless process used for propellants. These compositions all contain a high percentage of solid high explosive. They were investigated to determinate the suitability of the Holtex type explosive developed by Hispano Suiza of Switzerland, France and Spain, but for which the composition was not reported (Ref a). Compositions similar to Veltex No. 448 and containing 60% to 80% HMX, with either nitroglycerin or triethyleneglycol dinitrate as colloiding agent for nitrocellulose, have also been prepared. In general these compositions showed lower heat stability than that of conventional high explosive compositions.

Reference: 84

(a) U.S. Air Intelligence Information Report IR-269-55, Holtex--Hispano Suiza Explosive, 4 May 1955.

⁸⁴See footnote 1, page 10.

* U. S. GOVERNMENT PRINTING OFFICE : 1971 O - 430-508(6832A)

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